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ORIGINAL ARTICLES.

I.—Plant Cuticles from the Coal-measures of Britain.

By Lucy Wills.

(PLATES XXX AND XXXI.)

1. Introduction.

OUR knowledge of the structure of the cuticle of Coal-measure plants is very meagre in comparison with the amount of information recently published as to the cuticular characters of Mesozoic genera. So far as I know, no detailed descriptions have been published of the cuticles of British Palæozoic plants. Professor Zeiller[1] has described a few cuticles of French Carboniferous plants, and Dr. Huth[2] recently gave an account of the cuticle of *Mariopteris muricata*, but very little has so far been attempted in this branch of research. The present preliminary account deals with material obtained by Mr. L. J. Wills from the Middle Coal-measures of the Denbighshire Coal-field near Chirk and from the Old Hill Marls (Etruria Marls?) in the Upper Coal-measures of South Staffordshire. The cuticles are preserved as brown films in clayey shales, approaching fireclays in composition, none having yet been found in carbonaceous or sandy shales. It is hoped that this note will incite collectors to search for further specimens in this state of preservation.

The chief interest of the discovery of actual plant cuticles is that they afford a new weapon with which to attack the palæobotanical problems of the Coal-measures. The fact that different parts of the plant are preserved in this way may lead, on further investigation, to a correlation of these parts and to the identification of detached fragments. I have been unable in the time available to examine in any detail the spores and seeds collected, but I have made preparations of both macrospores and microspores from the cones of different species of *Lepidostrobus* and of platyspermic seeds of the *Cordaites* type and others of unknown affinity. I hope in the future to investigate these more fully.

The following account records briefly the results obtained from an examination of the leaf cuticles of several different species.

2. Method of Preparation.

The methods of preparation employed are those which have yielded much valuable information as to the cuticular structure in many Mesozoic forms.[3] The cuticles were soaked off the shale, treated with

[1] R. Zeiller, *Houille et Perm d'Autun et d'Epinac*, p. 115.

[2] W. Huth, *Palæobot. Zeitsch.*, Bd. i, pp. 7–14, 1912.

[3] For details of this method see A. G. Nathorst, *Palæobot. Zeitsch.*, Bd. i, p. 26, 1912, and H. H. Thomas and N. Bancroft, Trans. Linn. Soc., vol. viii, pt. v, p. 157.

Schülze's macerating fluid, and then washed in ammonia. The bleached cuticle alone remains after this treatment. The two surfaces of the leaf when present were separated by careful teazing with needles. The preparations were stained with either Bismarck brown or diamant fuschin.

3. Description.

Neuropteris heterophylla, Brongn.

Localities: Preesgwyn and near Cefn. Horizon: Middle Coal-measures.

The general form and venation of the leaflets are indicated in Pl. XXX, Fig. 1. Under the microscope the leaflets show two distinct types of cuticular structure; both types possess the following common features. The cells of both the upper and lower epidermis are roughly polygonal in outline, except over the vein-courses, where they are rectangular and elongated in the direction of the venation. The cell-walls are of a normal thickness and straight. On one surface the stomata are fairly numerous, approximately sixty-eight to the square millimetre, while on the other there are only a few scattered ones. On both surfaces they are restricted to the areas between the vein-courses.

The stomata (Pl. XXX, Figs. 2, 3, 4, 5, *S*) are irregularly arranged. Each individual one (Text-fig. 1) is nearly spherical in shape. The guard-cells are slightly sunk, lightly cuticularized, and sometimes imperfectly preserved. The cells surrounding the stomatal cavity, generally five or six in number, are similar to the other epidermal cells, but take a deeper stain; where they abut on to the stomatal cavity they form a solid ring of thickening (Pl. XXX, Fig. 4).

The distinguishing feature between the two types is the presence of small papillate hairs on one surface of the leaf in type β and their absence in type *a*. As there are corresponding types of *Cyclopteris* leaflets (*Cyclopteris* is a name given to one type of *Neuropteris* foliage), it would seem possible that two distinct species of *Neuropteris* are here represented. Further, in a few specimens of type *a* a marginal zone of water-stomata occurs (Pl. XXX, Fig. 2, *W*). This is of interest, as the same structure is found in the corresponding *Cyclopteris* type (Pl. XXXI, Fig. 7) and in some modern forms.[1] These stomata are similar in structure to the ordinary air-stomata but larger, more circular in outline, and with a less prominent ring of thickening round the stomatal cavity (Pl. XXX, Fig. 2; Pl. XXXI, Fig. 7). Certain of these stomata have a thin walled tissue in the stomatal cavity in place of the normal two guard-cells.

In addition to the two types described two specimens show glandular patches on certain cells of the single surface preserved (Pl. XXX, Fig. 5). These glandular cells, like the hairs in type β, are irregularly scattered over the whole leaf surface. No water-stomata have been observed in this type.

Leaflets of a *Neuropteris* have been collected from the Old Hill Marls, but have not yet been identified.

[1] G. Haberlandt, *Physiologische Pflanzenanatomie*, 1909, p. 449.

Cyclopteris sp.

Locality: Preesgwyn. Horizon: Middle Coal-measures.

Specimens examined show two types of epidermal structure similar to those described for *Neuropteris heterophylla*.

The form and venation of the leaflet is shown in Text-fig. 2. In several specimens both surfaces of the leaf were preserved and were separated; Pl. XXXI, Figs. 6, 7, represent the two surfaces of one fragment. The form and arrangement of the cells and stomata are illustrated on Pl. XXXI, Figs. 6, 7, and Text-fig. 3. Their close similarity to type *a* of *Neuropteris heterophylla* can be clearly seen by comparing these figures with Pl. XXX, Figs. 2, 5, and Text-fig. 1.

STOMATA AND GUARD-CELLS.

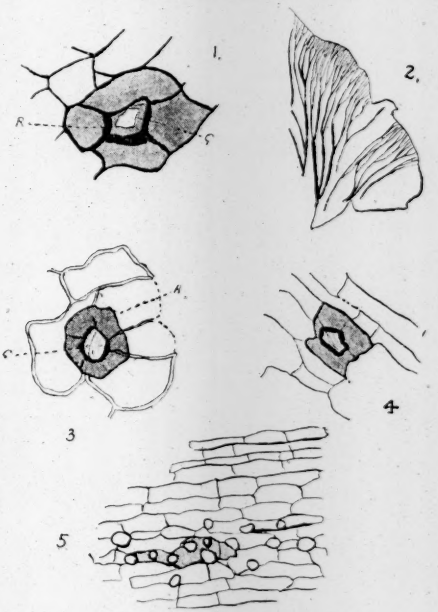


FIG. 1. *Neuropteris heterophylla*. *R*, ring of thickening; *G*, guard-cells.
,, 2. Half of a *Cyclopteris* leaflet.
,, 3. *Cyclopteris* sp. *R*, ring of thickening; *G*, guard-cells.
,, 4. *Cordaites* sp.
,, 5. *Cordaites* sp.

Water-stomata similar to those already described form a continuous band round the edge of that leaf surface which carries the numerous stomata.

Type *β*. The specimens classed under this heading are similar to those of type *a* in form, but are frequently not lobed. The one surface is slightly hairy and imperfectly preserved; the other shows cells of a normal structure and a few scattered stomata. Water-stomata have not been observed.

Alethopteris sp.

Locality: Preesgwyn. Horizon: Middle Coal-measures.

Both surfaces are preserved, but could not be separated. As in the two species already described the cells over the vein-courses are rectangular and elongated in the direction of the veins, those in the intervening areas polygonal.

The stomata can only be observed on one surface; they are fairly numerous, approximately eighteen to the square millimetre, and arranged in rows parallel to and between the vein-courses as shown on Pl. XXXI, Fig. 9. In structure the stomata are of the same type as in *Neuropteris heterophylla*. The guard-cells can be clearly seen in the stomatal cavity. The whole structure is similar to that described by Professor Zeiller for *Alethopteris grandini*, except that in the present case the guard-cells are also preserved. They are illustrated on Plate XXXI, Fig. 10.

Pecopteris sp.

Locality: Preesgwyn. Horizon: Middle Coal-measures.

Only one epidermal surface is preserved in this species. The cells are polygonal except over the vein-courses, where they are rectangular and elongated in the direction of the veins. No stomata have been observed in the specimens examined.

Cordaites sp.

Locality: Preesgwyn. Horizon: Middle Coal-measures. Locality: Old Hill, S. Staffs. Horizon: Upper Coal-measures.

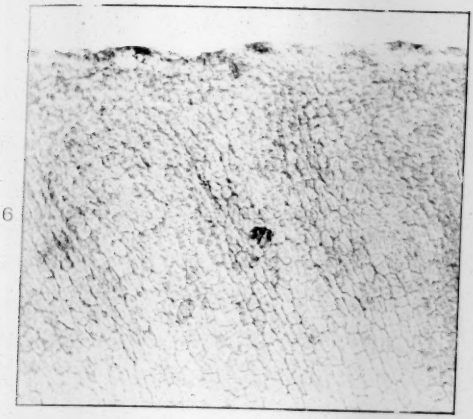
Preparations from several species have been made, all of which show the same cuticular structure. The two surfaces are preserved, but the one epidermis does not make good microscopic preparations; it shows, however, thin-walled cells and rows of stomata between the vein-courses. The other surface is well preserved. The cells are thick-walled, rectangular, and elongated in the direction of the vein-courses; those immediately above these being narrower and longer than those in the intervening areas (see Pl. XXXI, Fig. 11). There are a few stomata on this surface; they are oval in shape and arranged in rows parallel to the venation. The stomata are smaller than in the forms described above, and are frequently surrounded by four cells which form a ring of thickening round the cavity (Text-fig. 4). The guard-cells are lightly cuticularized and frequently imperfectly preserved. Circular structures of unknown significance occur at irregular intervals on the well-preserved surface (Text-fig. 5).

Thalloid growth.

Locality: Old Hill. Horizon: Upper Coal-measures.

A thalloid growth of uncertain affinity covers certain layers in the Old Hill Marls. A typical piece is figured on Pl. XXXI, Fig. 8. At first sight it appears to be formed of cutin, but since it dissolves in Schülze macerating solution it must be of a different chemical composition.

The fragments found measure as much as 10 mm. in length and average 1·5 mm. in breadth. They branch dichotomously and repeatedly. This fact, together with the lack of differentiation of



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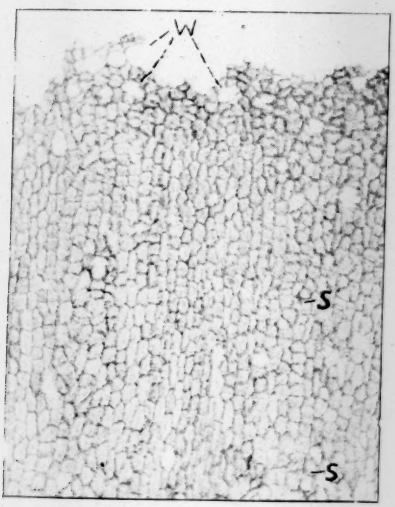

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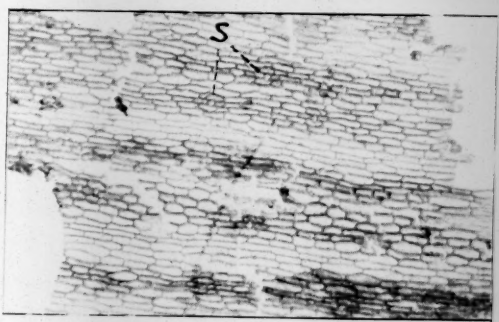

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W. Tams phot.

Plant-cuticles from British Coal-measures.

the tissue and the presence of spore-tetrads embedded in the thallus, points to the possibility of its being a primitive type of Bryophyte. Should further study support this view, these specimens will be of great interest as being the first Bryophytes recorded from the Palæozoic rocks.

4. Conclusions.

1. *Morphological.*—The chief interest in a study of the structure of a leaf cuticle centres round the stomata. In the specimens described above one type of stoma is common to all the species. The type is simple. A girdle of subsidiary cells surrounds the stomatal cavity, forming a ring of thickening where they abut on to it. The two guard-cells are slightly sunk in the stomatal cavity. The prevalence of this simple uniform type of stoma is of interest, since the cuticles examined by Professor Zeiller and Dr. Huth respectively showed distinct differences of stomatal structures, and in the case of *Alethopteris* the structure observed was interpreted differently by the two observers. Professor Zeiller[1] concluded that the guard-cells, which were missing in his specimen, were originally present but had not been preserved. Dr. Huth,[2] however, maintains that in all probability the guard-cells were never present, and that stomata were of an aquatic type similar to those in *Mariopteris muricata*. The description of the stomata of *Alethopteris* given above entirely bears out Zeiller's contention, but it is hoped that a further study will throw more light on this structural point.

2. *Ecological.*—The discovery of cuticular remains in the Coal-measures is of importance ecologically, since the epidermal features of a plant, especially the arrangement, structure, and number of the stomata, are intimately related to climate and habitat. Yet results based on the cursory examination of a few species can be of little value, and I do not propose to do more than make a few tentative suggestions. Dr. Huth has already suggested that the aquatic type of stoma found in *Mariopteris muricata* indicates an extremely humid atmosphere. The different types of cuticular structure found in *Neuropteris heterophylla* and *Cyclopteris* would seem to lend support to this view, for such authorities as Warming[3] and Haberlaudt[4] cite water-pores, glandular patches, and hairs on the epidermis as characteristics of plants living under humid conditions. If we assume that these structures functioned as hydathodes it is probable that the hairs and glandular patches occurred on the lower surface of the leaf and the water-stomata on the upper. If this be so, the stomata are more numerous on the upper surface, a feature which is consistent with the view that the plants were hygrophytic. Yet the number of stomata is less than might have been expected under such circumstances.

3. *Phylogenetic.*—It is possible that the structure of the stomata may eventually prove of use in tracing the phylogeny of modern forms. Suggestive in this respect is the similarity between the

[1] R. Zeiller, op. cit.
[2] W. Huth, op. cit.
[3] E. Warming, *Ecology of Plants*, English trans., 1909, p. 101.
[4] G. Haberlaudt, op. cit., pp. 445, 451.

stomata in these Palæozoic types and those of certain Cycads described by Messrs. Thomas and Bancroft.[1]

In conclusion I would like to express my gratitude to Professor A. C. Seward for many valuable suggestions and criticisms, and to Mr. Hamshaw Thomas, of Downing College, Cambridge, who gave me numerous useful hints on the methods of preparing and mounting the cuticles. I wish also to thank my brother, Mr. L. J. Wills, for very kindly placing the material at my service and for his encouragement during this research.

EXPLANATION OF PLATES.

PLATE XXX.

FIG. 1. *Neuropteris heterophylla*, Brongn. Leaflet. × about 4.
,, 2. ,, ,, Stomata *S*, water-stomata *W*. × 50.
,, 3. ,, ,, Group of stomata. × 50.
,, 4. ,, ,, Stomata. × about 167.
,, 5. ,, ,, Glandular patches *G*, stomata *S*. × 50.

PLATE XXXI.

FIGS. 6, 7. *Cyclopteris* sp. Type α. Two surfaces of same leaflet. Stomata *S*, water-stomata *W*. × 50.
FIG. 8. The cuticle of a dichotomously branched thalloid structure. × 17.
,, 9. *Alethopteris* sp., showing rows of stomata. × about 24.
,, 10. *Alethopteris* sp., stomata, guard-cells *G.C.* × about 167.
,, 11. *Cordaites* sp., stomata *S*. × 50.

The Text-figures are all camera-lucida drawings of the actual specimens.

II.—A New Trilobite from the Millstone Grit of North Yorkshire.

By W. B. R. King, B.A., F.G.S.

(PLATE XXXII.)

THE highest beds of the Carboniferous rocks of Wensleydale are found on the summit of Great Shunner Fell, which is situated on the watershed between Wensleydale and Swaledale, and forms the high ground to the west of the Buttertub Pass on the road between Hawes and Muker.

At a point 650 yards south-west of the Currack of Great Shunner Fell, called Shunner Fell Well on the 6 in. to a mile ordnance map (Yorkshire, Sheet L), a thin band of limestone and calcareous shale is seen forming a conspicuous feature. A detailed section of the beds exposed at this locality shows about 12 feet of calcareous beds. The limestone in question is described in the Geological Survey memoir on *The Geology of the Country around Mallerstang, etc.*, where the following description of the Millstone Grit of that area is given "The overlying bed is a very thick shale, which forms the greater part of Shunner Fell. In it there are two thin bands of fossiliferous limestone, which are to be seen near Shunner Fell Well on the west side of the hill. In one of these Mr. Goodchild found a trilobite. A tiny outlier of grit forms the extreme top of Great Shunner Fell."[2]

[1] H. H. Thomas and N. Bancroft, op. cit., pp. 155–204.

[2] *The Geology of the Country around Mallerstang, etc.* (Mem. Geol. Surv.), 1891, p. 145.

The limestone bed is a little over 500 feet above the base of the Millstone Grit as defined in the above-mentioned memoir.[1] Mr. J. Pringle has kindly identified the fossils from these beds, and has drawn up the following list :—

Athyrid.
Chonetes laguessiana, de Kon.
Ch. sp. (papilionaceous var.).
Lingula squamiformis, Phill.
Martinia glaber (Mart.).
Productus cf. *longispinus*, J. Sow.
P. sp. (*semireticulatus* group).
Schizophoria resupinata (Mart.).
Spirifer bisulcatus, J. de C. Sow.
S. sp.
Posidoniella lævis (Brown).
Pseudamusium fibrillosum (Salter).
Glyphioceras bilingue (?) (Salter).
Orthoceras sp.
Cladodus mirabilis (?), Ag. (tooth).

These specimens are now in the Jermyn Street Museum, the registration numbers being Z 333–74.

Mr. R. G. Carruthers has sliced several Corals, which were obtained from the highest limestone bed, and has identified *Zaphrentis costata* and *Z. constricta*; the latter, he remarks, occurs normally in the Lower Limestone group of Scotland.

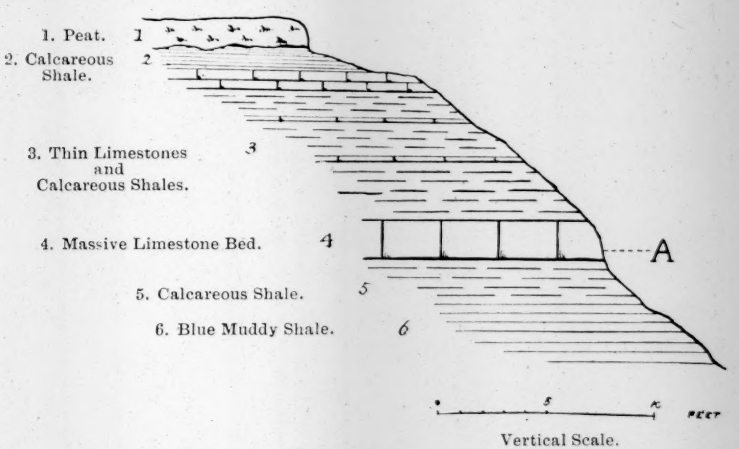


FIG. 1.—Section at Great Shunner Fell Well, Yorkshire.

A list of fossils, chiefly only with the generic names, is given in the Geological Survey memoir,[2] but the specimens are not preserved in the Survey collection.

The Millstone Grit underlying the calcareous beds of this area, although mainly comprised of grits and sandstones, and containing the Tan Hill coal and other thin seams, is essentially a marine formation, since many of the grits contain casts of *Spirifer* and Crinoids. The strata were evidently formed rapidly in a sinking area, and the change in character of the beds, resulting in calcareous deposits, may be due to failure in the supply of coarse material, aided by an increased depression of the area. As a result of this change to clearer

[1] *The Geology of the Country around Mallerstang, etc.*, 1891, pp. 11–12.
[2] Ibid., p. 160.

water conditions, there was a migration of more open water forms into the area.

The calcareous beds are probably on the same horizon as the Botany Beds of the Middleton in Teesdale district, the fauna of which Professor Garwood considers to be "the highest truly marine fauna yet met with in the North of England".[1] Although the fauna of the Shunner Fell Beds is in many respects unlike that of the Botany Beds, the want of similarity is probably due to a difference in the conditions of the sea at the time of deposition, rather than to any great difference in age. The presence of a well-marked marine horizon high up in the Millstone Grit on this area is of interest, as it tends to support Professor Garwood's view that the fauna of the Botany Beds migrated from the south-west or west.

The Trilobites are found throughout the calcareous beds, but are best preserved in one of the more massive limestone beds, marked A in the section (Fig. 1). They are found in many stages of growth, but appear to belong to one species. At first sight they resemble *Phillipsia Eichwaldi* (Fischer), but on close examination they are found to be a species of *Griffithides*. It would seem that this is one of the highest horizons at which Trilobites are found in England, and the forms might be expected to be somewhat modified. The specimens have been shown to Dr. H. Woodward, and he considers them to belong to a new species. As they are particularly well preserved and many complete specimens have been found, there is ample material from which to describe the species.

GRIFFITHIDES SHUNNERENSIS, nov. sp. (Plate XXXII.)

General outline, elliptical.

The measurements of an almost perfect specimen give the following results :—

Total length	2·15 cm.
Greatest breadth	1·03 ,,
Length of head	·7 ,,
Length of thorax	·55 ,,
Length of pygidium	·9 ,,

Head semi-oval, nearly as long as broad.

Glabella inflated, pear-shaped, expanded anteriorly, narrowing posteriorly, where it is elevated. The surface (when the original shell is preserved) is ornamented with fine granules; these are relatively larger in the young stages. When the shell is removed the surface appears perfectly smooth, although a few specimens show two slight undulations, which may mark the position of degenerate glabella furrows.

The basal lobes are well defined, triangular, and smooth.

The neck furrow is deep and curves in its central portion towards the glabella. The neck ring is broad and swollen, and is ornamented with one central tubercle and small granules, which are larger and more distinct on the posterior margin.

The fixed cheeks are narrow, with well-marked raised lobes at the eyes. The free cheeks have a small smooth raised portion, but the

[1] E. J. Garwood, Quart. Journ. Geol. Soc., vol. lxviii, p. 543, 1912.

surrounding border is broad, and ornamented by fine ribs, which run parallel to the margin. The cheeks are produced posteriorly to form conspicuous flattened spines, which reach to the sixth thoracic segment.

The eyes are three-tenths the length of the glabella; they are finely facetted and reniform.

Most of the specimens, when the original shell is preserved, show two depressions, one on either side of the glabella, above the eye-lobe.

Thorax consists of nine segments. The axis is slightly tapering, and is rather less than one-third of the total width of the thorax. It is ornamented with a single row of fine granules along the posterior border. The pleuræ are grooved and end rather squarely, although the anterior angle is slightly rounded, and the posterior angle is produced to form a very short blunt spine.

Pygidium semi-ovate in outline. Central axis elevated and tapering, but ending bluntly. It is composed of sixteen fused segments. The lateral lobes are ten in number. The axis is ornamented in the same manner as the thoracic axis. The lateral lobes are smooth. The pygidium is completely surrounded by a broad, slightly curved border, the margin is entire.

Hypostome similar to that of *Phillipsia Eichwaldi*,[1] length two-thirds that of the glabella. Upper border curved anteriorly. The oblong raised central portion is parallel-sided, and ornamented by small pits. There are two posteriorly directed oblique furrows on the lower parts of this raised portion. The wings are broadest in the upper portions, where their breadth is equal to the total length. From the place of greatest breadth they narrow rapidly towards the centre of the hypostome and then follow the raised axis; their lower portion is well developed, and ends bluntly with rounded angles. The surface of the wings is finely ridged; these ridges are specially well-developed in the broader parts. (See Plate XXXII, Fig. 3.)

This species, although in many respects similar to *Phillipsia Eichwaldi* (Fischer), differs from it, firstly, in having no well-marked glabella furrows; secondly, the lobe over the eye is much more developed in the Shunner Fell species; and thirdly, the pygidium is of a slightly different outline.

The only species of *Griffithides* with genal spines of similar proportions is *G. longispinus* (Portl.). The whole shape of this species is quite different. *G. acanthiceps* (H. Woodward) is of similar appearance, but its pygidium has only thirteen segments. The figures of *G. calcaratus* (McCoy) are not good enough to identify a specimen from; moreover, its glabella is said to be smooth.

Many theories have been advanced as to the use of the 'pores' on the glabella of Trilobites. The subject is discussed by Dr. Woodward in an appendix to his work on the Carboniferous Trilobites in the Memoirs of the Palæontographical Society.[2]

The following are among the suggestions which have been put forward: that they were points of attachment of external antennæ;

[1] H. Woodward, *Carboniferous Trilobites* (Palæont. Soc.), pl. iv, fig. 4.
[2] Ibid., 1884, pp. 71–6.

that they were the places where the muscles working the hypostome were attached; or that they were ocelli. Moreover, the different authors do not agree as to whether they were perforations in the shell, or merely depressions.

It may not be out of place here to add a few notes on these 'pores' as exhibited in the above described species. The pores are situated just in front of the eye-lobe, on the furrow separating the glabella from the fixed cheek. The surface of the shell immediately surrounding the depression is smoother than the rest of the glabella. In well-preserved specimens the depressions appear as deep oval pits in the shell, with their longer axes parallel to the length of the glabella. When observed from the under side the shell is seen to be bent downwards to form a slightly hollowed cone. A section through the pore shows that the shell is not perforated, but rather thickened on the margins of the cone, while the inside of the cone is flattish and rough. The shell forming the rim and inner portion of the cone seems, however, to be of a different nature to the rest of the glabella, being somewhat lighter in colour. This lighter portion also forms the base of the upper funnel-shaped depression (Fig. 2).

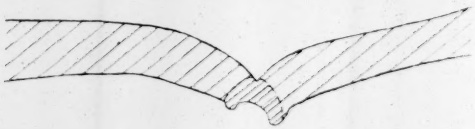


FIG. 2.—Section through pore just in front of the eye-lobe on the furrow which separates the glabella from the fixed cheek.

The function of these pores is difficult to decide; but the rough surface of the under side of the cone suggests a place of muscle attachment; if this be so, it would agree with M. Barrande's contention, but against this there is the difference in the ornamentation of the upper surface and the change in the character of the shell, which would seem to indicate the presence of some sense organ.

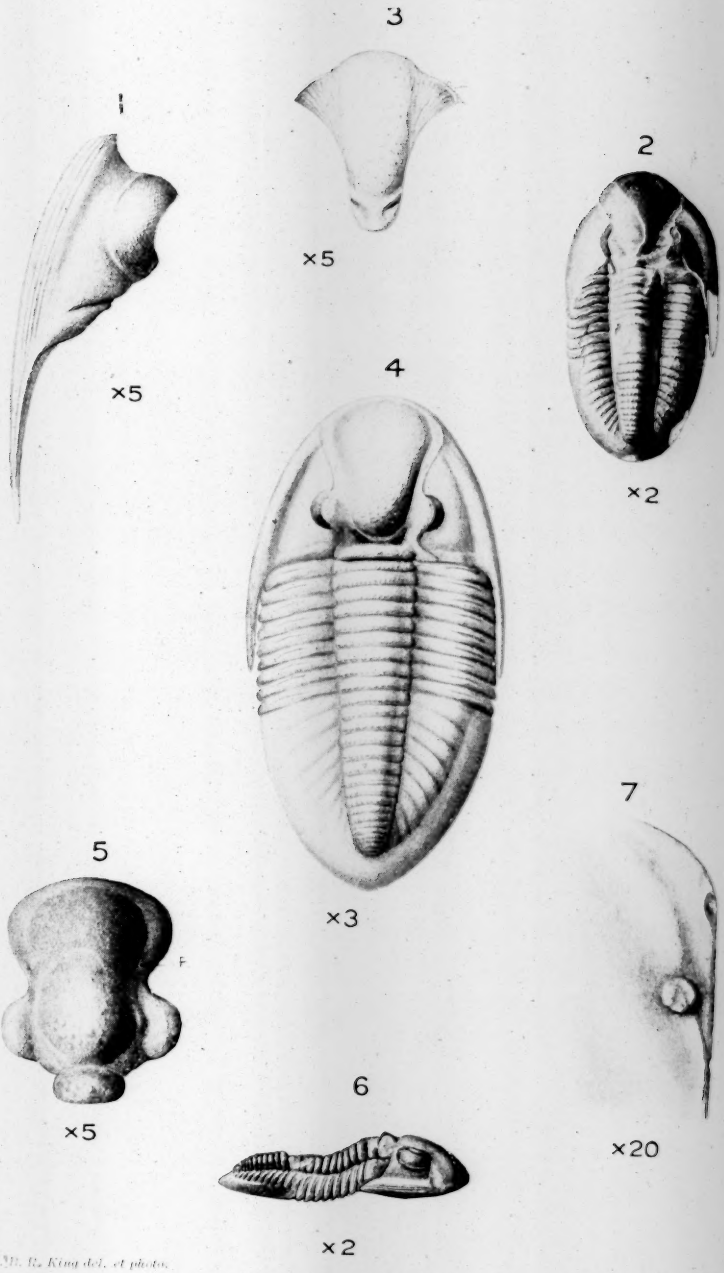
In conclusion I have to thank Professor T. McK. Hughes and Dr. H. Woodward for much help in working out the Trilobites, and Dr. J. E. Marr, at whose suggestion I first visited Shunner Fell. I have also to thank Messrs. A. W. R. Don and H. T. Kennedy, of Trinity College, Cambridge, and Mr. R. Hodgson, of Hawes Junction, for helping me to collect the specimens.

EXPLANATION OF PLATE XXXII.

FIG. 1. Free cheek and eye, showing facettes. × 5.
,, 2. Almost complete specimen. × 2.
,, 3. Restoration of hypostome. × 5.
,, 4. Restoration. × 3.
,, 5. Glabella of young specimen showing granulated surface and large lobes. *P*. position of 'pore'. × 5.
,, 6. Side view of almost complete specimen. × 2.
,, 7. 'Pore' seen from the under side. × 20.

Figs. 1, 2, 5, 6, 7 are photographs.

Note.—These specimens are now in the Sedgwick Museum, Cambridge.



W. H. K. King del. et photo.

Griffithides Shunnerensis, King, sp. nov.

III.—The *Cheirotherium*.

By D. M. S. Watson, M.Sc., Lecturer in Vertebrate Palæontology in University College, London.

ALTHOUGH educated Europeans have never carried the art of 'spooring', or tracking, to the perfection with which it is employed by the Australian and African natives, it is possible for us by applying a little common sense and certain experience of the tracks of living beasts to the fossil footprints so commonly found in terrestrial deposits laid down under arid conditions to find out many features of the animals which made them.

The tracks of *Cheirotherium* are commonly found in the Trias of Britain and Germany. They occur in the Bunter and the lower part of the Keuper, the faunas of which rocks are still very imperfectly known in Europe. The most marked features of a Cheirotheroid track are—

1. That there are impressions of all four feet.
2. That the fore-feet are very much smaller than the hind.
3. That the hind-feet are always the more deeply impressed.
4. That the track is extremely narrow, the feet of the two sides being planted nearly on the same line.
5. That the stride is long.

1. Shows that the animal was four-footed.
2. That the fore-legs were feeble in proportion to the hind.
3. That the animal was very nearly balanced about its pelvis.

There are two ways in which such a balance can be arrived at; either the beast stands bolt upright like a meer-kat (*Suricata*) or a man, or it has a tail as long and massive as its body. The fact that *Cheirotherium* habitually touched the ground with its fore-feet shows that it must have adopted the latter method and have had a large massive tail.

The fact that the track is very narrow shows that *Cheirotherium* was a very good walker; any animal which has a wide track, like a tortoise, has to swing from side to side whilst it is walking in order to keep its centre of gravity over its track, and in doing so wastes a large amount of muscular energy. Every animal which carries its feet so close together that its track is nearly a single line must have special arrangements to prevent it from kicking itself when running, and is consequently likely to have well-ossified and 'finished' limb-bones. An animal with a narrow track must, if it is to be efficient, have a pelvis which is very narrow between the acetabula compared with the length of its limb-bones; if it be otherwise, then, when the animal is viewed from the front, the femur will not be in a vertical plane, the animal being 'knock-kneed', a position which keeps the abductors constantly in strain. *Cheirotherium* was thus a four-footed animal with relatively small fore-legs and long heavy tail and narrow pelvis. The very considerable stride, about a metre in the case of the commonest British species, shows that it was at least as long in the leg as a man.

The groups of animals known, by the discovery of their bones, to have been in existence in Europe during the time of the *Cheirotherium* are—

1. The Stereospondylous Stegocephalia. The limbs of these amphibia are extremely imperfectly known, but the materials of *Mastodonsaurus* and *Metoposaurus* show that, like all the Permian Stegocephalia, they had very short legs, the humerus and femur being carried at right angles to the body and the track necessarily very wide. The apparent rarity of caudal vertebræ suggests that the tail

FIG. 1.—Footprints of *Cheirotherium*.

was short. Furthermore, it is rendered probable by the enormous size of the head, which must have carried the centre of gravity very far forward, that the fore-feet were larger than the hind.[1] They can therefore have had nothing to do with *Cheirotherium*.

[1] The Stuttgart material of *Mastodonsaurus*, when examined in the light of the now well-known *Eryops*, shows clearly that Dr. Fraas's familiar restoration of the pelvis is quite wrong; his 'ilium', as shown conclusively by the occurrence of a specimen lacking the pubis, and of an isolated ischium, is really the whole os innominatum, nearly identical with that of *Eryops*. Dr. Fraas's pubis is an ischium, and his ischium a scapula-coracoid extremely similar to that of *Eryops*. There is also a humerus, figured by Pleininger many years ago, which, except that it is rather more slender, perfectly resembles that of *Eryops*.

The few Cotylosaurian reptiles known from the European Trias are all very small lizard-like animals, and as all known members of this group have a very wide track they could not have been the makers of the *Cheirotherium* footprints. The limbs of the remarkable primitive Phytosaurian from the Bunter of Bernberg described by Jaekel as *Palæorhinus* are quite unknown, but there is every reason for believing that they resembled those of the later form *Mystriosaurus*, which is shown by MacGregor's description of an American form, and generally resemble those of modern crocodiles in proportions; these animals of course make a quite different type of track to *Cheirotherium*.

Other important Triassic groups are the Tortoises, which make an extremely characteristic spoor, with the feet of opposite sides widely separated, and each individual print very short from back to front, with the impressions of claws standing clear of the sole.

2. *Hyperodapedon*, the track of which must have been like that of a heavily built lizard.

3. The Lizards themselves, which make a sprawling track, are of course quite out of the question.

As *Cheirotherium* tracks are always found in terrestrial deposits, and even in rocks which we have reason for believing were laid down under arid conditions, it is unnecessary to discuss the marine groups of the Ichthyosauria, Sauropterygia, and Placodontia. The only remaining groups are the lightly built Thecodonts, of which *Aetosaurus* and *Ornithosuchus* are the best-known members, and the Dinosaurs. These groups differ only slightly in structure, and it is almost certain that the latter is derived from the former. The differences lie almost entirely in the limbs. The fact that the proximal tarsals of the Thecodonts are not rigidly articulated to the tibia and fibula suggests that the whole foot was placed on the ground as in a lizard. The whole structure of the hind-leg suggests that it was carried in a somewhat lizard-like manner with the femur at a considerable angle with the body and the various sections of the leg considerably flexed. This opinion is supported by the fact that the acetabulum is imperforate, and also by the actual position of the legs in the type-specimens of *Aetosaurus*, in which the animals still, to a large extent, retain the form they had during life.

There remain only the Dinosaurs, which in the known Triassic forms seem to have been generally bipedal, and resemble *Cheirotherium* in having long heavy tails, so that the animal is balanced about the pelvis, in the small size of their fore-legs, in the narrowness of the pelvis, in the length of the leg, and in the narrowness of their track. There can, in fact, be no doubt that *Cheirotherium* was a Dinosaur or direct Dinosaur ancestor.

It remains to compare the actual footprints with known Dinosaurian feet. The excellent work of Lull on the American tridactylous footprints from the Trias of Connecticut, which he has successfully correlated with the lightly built carnivorous forms, such as *Anchisaurus*, shows that we must look elsewhere for *Cheirotherium*. The typical lightly impressed print of a Cheirotheroid pes has five digits, of which the third is the longest and the fifth is turned

outward and backward. The first and second toes often show traces of distinct pads, there being two on the first and three on the second digit. It is obvious, from inspection of good prints, that these pads lie below the articulations, as in Dr. Lull's Dinosaurs, and not between them as in ourselves. The distal end of each digit ends in a small claw, which extends beyond the pad. The posterior ends of the pads of the toes are separated when lightly impressed and represent the articulation between the lower ends of the metatarsals and the first phalanges.

The sudden termination of the pads behind shows that the metacarpus was carried clear of the ground, i.e. that the animal was digitigrade. In some exceptional specimens the pads run into a distinct sole, as is, for example, the case in the type-specimen of *Cheirotherium herculis*; in such cases, which may represent a resting position, the 'heel', which is presumably made by the metacarpus, is slightly longer than the phalangeal part of the impression. The

FIG. 2.—Restoration of *Plateosaurus* from specimens in the Berlin Museum. After an outline figure by Professor Jaekel, in *Die Woche*, Hft. xxvi, Berlin, 1912.[1]

fifth digit, which we have not hitherto considered, lies in an extremely curious position with its very large posterior pad behind the third digit. The whole arrangement suggests that the metatarsal acted as a sort of strut to the tarsus, the other four metatarsals standing not quite vertically, but at some angle between that and horizontally. It is, unfortunately, impossible to determine the number of phalanges in this toe, but it is not improbable that there were only two. No known Triassic Dinosaur has so well-developed a fifth toe as *Cheirotherium*, but the foot of *Plateosaurus* seems to me not very dissimilar, and it is quite possibly a descendant of that animal. The further reduction of the fifth digit in most Dinosaurs may conceivably be due to the fact that when the metatarsus became vertical its use as a strut disappeared, and, as no other use for it presented itself, it was rapidly aborted.

[1] [This Text-figure, from the *Guide to Friar Park, Henley-on-Thames* (1914), p. 27, fig. 12, was kindly lent by Sir Frank Crisp, Bart. (The scales have been added, and are not in Professor Jaekel's outline figure.)—ED. GEOL. MAG.]

IV.—On the Triassic and Permian Rocks of Moray.

By D. M. S. Watson, M.Sc., and G. Hickling, D.Sc.

Some time ago one of us [9] showed that the 'New Red Sandstone' rocks of Morayshire may be divided into three groups, two of which are of Permian age and the other Triassic. The recent very rapid increase in our knowledge of Permian and Triassic reptilian faunas allows of a closer correlation than was attempted in the former paper.

To the fauna of the Trias two new types have been added from the Lossiemouth quarries, viz. *Brachyrhinodon Taylori*, v. Huene [5], a Rhynchocephalian, and *Saltopus Elginensis*, v. Huene [4], which is said to be a Dinosaur. None of the Triassic species, except *Hyperodapedon Gordoni*, is known from any other locality, so that there is little direct evidence of their age, but Professor v. Huene, whose experience of Triassic faunas is unrivalled, believes them to be of the same age as the Lettenkohle [6], a determination which may be provisionally accepted.

Whatever the precise horizon, the absence of Labyrinthodonts is remarkable (it now seems certain that *Dasygnathus* does not belong to that group), but is probably to be explained by the prevalence of desert conditions. All the species known from Elgin appear to be dry-land types.

No new types have recently been added to the Permian group from Cuttie's Hillock Quarry. The species there present are *Gordonia Juddiana*, E. T. Newton, and four other species; *Geikia Elginense*, E. T. Newton; *Elginia mirabilis*, E. T. Newton.

Gordonia is a typical '*Dicynodon*' and agrees very closely with certain specimens of that genus from the *Cisticephalus* zone of the Karoo, of Upper Permian age.

Geikia is a more interesting and unusual type. It is not closely paralleled by any other known form, but is simply derived from *Dicynodon* by the development of horns on the nasals. Among the types in the *Cisticephalus* zone of South Africa a similar tendency is observable, though in a less degree, in the development of slight thickenings or even distinct knobs, which may be regarded as 'rectigradations' of the *Geikia* horns. The *Cisticephalus* zone is the equivalent of the *Pariasaurus* beds of the Russian Dwyna, which are shown by the occurrence of marine fossils to be Upper Permian.

Elginia is related to *Pariasaurus* as is *Geikia* to *Gordonia*. Its great spinosity is a very advanced character. The typical Pariasaurians of the *Pariasaurus* zone of South Africa are only moderately ornamented with bosses and scutes. Those from the higher *Cisticephalus* zone (e.g. *Propappus*) show a much greater development of dermal armour and a further increase in spinosity. Judging from Professor Amalitzski's photographs, the types from the equivalent Upper Permian horizon of Russia are also very much ornamented and much covered with scutes, although none are known to be so spinous as *Elginia*, which represents the acme of spinosity in this group. The undetermined sacrum from Elgin figured by Newton is undoubtedly Pariasaurian and almost certainly belongs to *Elginia*. This specimen

also indicates a very advanced type, from the loss of the intercentra between the lumbar vertebræ which are preserved.

The indications of these three reptiles as to the age of the Cuttie's Hillock Beds is therefore very clear and consistent, viz. that they are slightly younger than the Upper Permian Pariasaurian beds of Russia or the *Cisticephalus* zone of South Africa; being thus at the extreme top of the Permian or about the Permo-Triassic boundary. A feature of great general interest is that by their occurrence in these rocks these three reptiles are shown to be dry-land or even desert animals.

The Cummingstone Beds have still only yielded footprints. Some time ago one of us showed that these impressions belong to the same types as those at Mansfield, Dumfries, Penrith, and Exeter, two forms being common to Mansfield and Cummingstone [2, 3]. A further examination of the material in the Elgin Museum, and of numerous imperfect tracks in the Cummingstone quarries, completely

FIG. 1.—*Chelichnus* sp. × ½. This footprint agrees exactly in form with those figured (but not named) by Huxley as the smaller impressions from Cummingstone (Huxley, *The Crocodilia of the Elgin Sandstones*: Mem. Geol. Surv., Monograph iii, 1877, pl. xv, figs. 1–4, pl. xvi). It differs in being twice as large. The photograph shows two associated natural casts in relief. The upper one represents a deep impression, showing the characteristic crescentic mound of sand in the rear. The lower one is a lighter impression, without the mound, but showing the claw markings well. This type of footprint is much the most common throughout the Upper Permian of Britain. Locality: 300 yards W.N.W. of 'Elginia' Quarry, Cuttie's Hillock, Elgin.

confirms this identification. The occurrence of the Mansfield tracks in the Magnesian Limestone definitely fixes their age as Upper Permian (Zechstein) [8], a determination supported by the widely distinct character of the vertebrate tracks known from the Lower Permian (Rothliegende) of Thuringia [7] and Hampstead [1]. The Cummingstone Beds must, therefore, be of nearly the same age as the Cuttie's Hillock Elginia deposits. That such is actually the case is conclusively shown by our fortunate discovery of one of the typical Cummingstone footprints in a quarry distant only 300 yards W.N.W. from the Cuttie's Hillock reptile quarry (see Fig. 1). The evidence

of the footprints and the reptiles is thus mutually confirmatory of the Upper Permian age of these rocks.[1]

Mode of Origin of the Deposits.—The Permian and Trias are typical 'red rocks' in this area, of the same general type throughout. They are yellow and white sandstones and conglomerates, strongly false-bedded; they contain scattered pebbles in lenticular patches, rarely forming regular conglomerates; the fossils are distributed in the same irregular manner, never in regular beds. These are emphatically the characteristics of terrestrial, not of aqueous deposits, and we would suggest that throughout this great interval the district was continuously a land-surface, on which all these deposits gathered as drifting sand. In this way we may understand why an apparently quite thin series of rocks represents so great an interval of time, and yet no visible unconformity has ever been found. The Permian and Triassic reptiles all appear to have been terrestrial, except perhaps *Hyperodapedon* and *Stenometopon*, which may have been river forms.

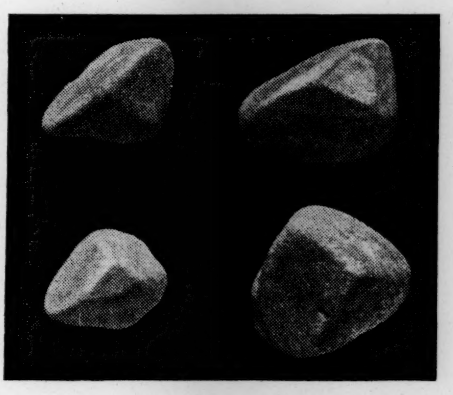


FIG. 2.—Dreikanter from the Upper Permian of Cuttie's Hillock Elgin, 200 yards north-east of 'Elginia' Quarry.

The emphatically 'desert' character of the Permian in the 'Dreikanter' quarry of Cuttie's Hillock has been previously described and is here illustrated by a better photograph of some of the typical dreikanter (Fig. 2). Finally, we may suggest that the curious 'cherty rock' in the Trias at Stotfield, Lossiemouth, finds its nearest modern parallel in the superficial chalcedony which develops over the sands in certain dry sandy regions such as the Fayum.

[1] It may be observed that one of the tracks from Dumfries among the Jardine Collection in the Edinburgh Museum (middle slab in Cases 1 and 2) appears to be specifically identical with Huxley's *Chelichnus megacheirus* from Elgin. The pair of slabs at the top of Case 8 in the same collection may represent the species here figured from Cuttie's Hillock. Possibly also the very large prints from Cummingstone figured by Huxley (of which several good examples are preserved in the Elgin Museum) may be Jardine's *Chelichnus titan*, but the preservation of the latter is too imperfect for close comparison.

Summary.—(1) The reptiles *Gordonia*, *Geikia*, and *Elginia* are shown to be slightly later than those of the Upper Permian *Pariasaurus* beds of Russia, or those of the equivalent *Cisticephalus* zone of South Africa. They therefore represent the extreme top of the Permian. (2) The remaining Elgin reptiles are Middle Triassic (? = Lettenkohle of Germany). (3) The Elgin footprints are widely distinct from Triassic forms and from those of the Lower Permian, while agreeing exactly with the group associated with the Magnesian Limestone of England. They therefore represent the extreme top of the Permian. (4) The discovery is recorded of one of the typical footprints in close proximity with the Permian reptile quarry. (5) The Permian rocks occupy the west of the 'Triassic' area, the true Trias the east. (6) It is suggested that the area was a land-surface during Permian and Triassic times.

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V.—NOTE ON THE HIGHLAND BORDER SERIES, NEAR ABERFOYLE.

By T. J. JEHU, M.A., M.D., F.R.S.E., F.G.S., Lecturer in Geology at the University of St. Andrews.

THE rocks of this series form an interrupted belt along the southern border of the Highlands from Stonehaven on the east to the island of Arran on the west, and they appear again on a more extensive scale in Ireland. In Scotland the series consists of cherts or jaspers and shales, sometimes associated with limestones and with some peculiar igneous rocks. The age of the series has been for years a matter of controversy. Many geologists have held that these rocks are of pre-Cambrian age, but Messrs. Peach & Horne in their volume on *The Silurian Rocks of Britain* (Mem. Geol. Surv., 1899) remarked on the close resemblance of the rocks of this belt to some of the Arenig rocks in the Southern Uplands of Scotland, and the belt has been marked on the Geological Survey maps as doubtfully Lower Silurian.

Many years ago the remains of Radiolaria were detected by Dr. Peach in the cherts near Gualaan, east of Loch Lomond. Later Dr. R. Campbell recorded the discovery of fossils in the black shales, jaspers and cherts intercalated in a series of crushed green igneous rocks north of Stonehaven (GEOL. MAG., N.S., Dec. V, Vol. VIII, 1911).

The discovery of fossils in the Chert and Black Shale Series at Aberfoyle was announced in *Nature*, June 6, 1912, and a further communication was made at the meeting of the British Association, Dundee. The fossils were found in pale-grey chert bands, 1 to 3 inches thick, in an exposure on the south-east side of the Bofrishlie Burn, about 400 yards north-west of Arndrum. The remains occur in muddy films in the chert. The great majority of the fossils are hingeless Brachiopods. The collection was submitted for examination to Dr. Peach, who determined the following forms:—

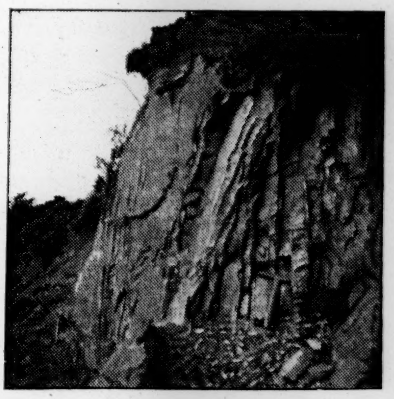

FIG. 1.—The fossiliferous Chert beds, Aberfoyle.

BRACHIOPODS.

1. *Acrotreta*. Specimens of this genus are by far the most common. There appear to be many examples of the species *A. Nicholsoni*, Dav. This is a form common in the Glenkiln (Upper Llandeilo) Black Shales. It occurs in Arenig, Llandeilo, and Bala rocks in the Southern Uplands.
2. *Obolella*. Species indeterminate; several specimens found. In one, the first fossil discovered in the region, both the external and internal casts are shown.
3. *Obolus*. Species indeterminate; a few specimens found.
4. *Lingulella*. Species indeterminate; several specimens found. One specimen shows the internal septum.

PHYLLOCARID CRUSTACEANS.

Two specimens were obtained which appear to be allied to *Lingulocaris*.

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The flattened chetæ of Polychæte worms, longitudinally striated, like some which have been described by Walcott. Annelid jaws.

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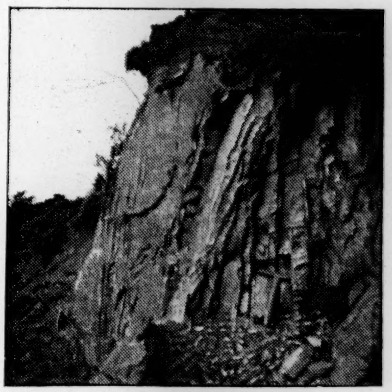

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Two specimens were obtained which appear to be allied to *Lingulocaris*.

ANNELIDS.

The flattened chetæ of Polychæte worms, longitudinally striated, like some which have been described by Walcott. Annelid jaws.

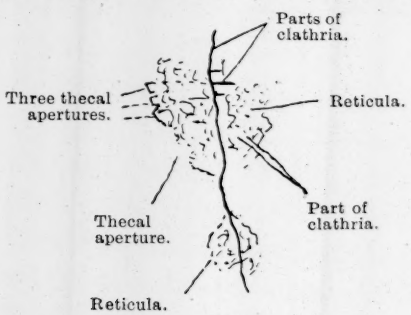
OTHER OBSCURE FORMS.

Among these are what may possibly be pieces of skin of an Arthropod allied to *Eurypterus*. An obscure Graptolite referred to later.

The following remains were found in cherts on the hill-top just above the road where the old aqueduct crosses the valley, opposite the Drum of Clashmore :—

1. Flattened chetæ of annelids preserved in iron pyrites.
2. Casts from which iron pyrites nodules have sprung out and which look very like the casts of Radiolaria.

The fossils obtained from this district were on exhibition at Dundee, at the British Association meetings, 1912, and they were examined by Dr. Ami, F.R.S. Can., of Ottawa. In a letter sent subsequently to Dr. Horne, he stated that the fossils closely resemble those obtained from Upper Cambrian beds belonging to the Quebec Group. His opinion was based partly on the Brachiopods and partly on the presence of an obscurely preserved Graptolite resembling *Retiolites ensiformis*, Hall, a type characteristic of the Sillery Sandstones of the Quebec Group (Upper Cambrian). The great interest attaching to the identification of a Graptolite from the Highland Border rocks was at once recognized, and the specimen was sent to Miss G. L. Elles, Cambridge, for examination. She has kindly supplied the following description:—



× 8.

FIG. 2.—SKETCH OF AN OBSCURE GRAPTOLITE FROM ABERFOYLE.

"The specimen appears to me to show traces of thecæ, with a fairly well-developed reticula and clathria. It would appear to belong to Retiolitidæ. The strands belonging to the clathria are the median longitudinal strand and several lateral fragments seen on its left side; those on the right are more obscure. The reticula is of much the same nature as that of *Plegmatograptus selula*, but this Graptolite has no well-developed clathria. Four thecal apertures are discernible, three close together on the extreme left and one some little distance below them. The fact that none are seen on the right is probably due to the fact that the left side of the polypary is turned towards the observer, the right being turned away."—*G. L. Elles.*

The evidence afforded by the fossils shows that the Highland Border Series is of Lower Palæozoic age—probably Upper Cambrian or Lower Ordovician. The field relations of the rocks of this series to the rocks which succeed them on the north are by no means clear. The working out of this problem will throw further light on the true stratigraphical position of the metamorphic rocks in the Southern and Central Highlands.

VI.—The Zone of *Offaster pilula* in the South English Chalk.

By R. M. Brydone, B.A., F.G.S.

II. Isle of Wight.

THE zone of *Offaster pilula* is probably exposed on the coast in West Sussex on the foreshore near Bognor, but the nearest cliff exposures to those of East Sussex are those of the Isle of Wight, at Culver Cliff and Scratchells Bay. In both of these the Chalk is so highly inclined that only a very small area of each bed can be reached; and the condition of the accessible surface is such as to make it most improbable that anything beyond the broad outlines of the subzone of abundant *O. pilula*, which is the key and pith of the zone of *O. pilula*, will be detected.

The first of these exposures in the natural order going westwards from Sussex is Culver Cliff, but that is notoriously abnormal, and it is better to take first Scratchells Bay.

A. *Scratchells Bay.*

One of the peculiarities of Scratchells Bay is that it offers only one secure landing-place, in the extreme east corner, under the Grand Arch, so that the middle of the bay, where the zone of *O. pilula* was to be expected, can only be reached by plodding past exposures of the zone of *M. cor-anguinum*, the *Uintacrinus* band, and the zone of *Marsupites*. It was necessary to identify the latter, or at any rate its highest beds, in order to get a starting-point for the zone of *O. pilula*, and I took the opportunity of attempting to identify the other boundaries which must be passed. The westward face of the Grand Arch I knew from Dr. Rowe's work[1] to be occupied by *cor-anguinum* chalk; this was abundantly flinty and seemed to be quite devoid of marl seams. For some way westwards along the bay the chalk continued to be flinty and marlless; then came a short outburst, some 10 feet across, of marly veins, at which I made close but fruitless search for *Uintacrinus*; then for some distance the chalk was again marlless, until there appeared a solitary definite seam of marl, in the neighbourhood of which I again made fruitless search for *Uintacrinus*. It was succeeded by more marlless flinty chalk, and then there appeared a strong tabular seam of flint, which was single in the upper part of the cliff, but forked at its base. Two and a half feet above this there was a strong marl seam, the first of many. Search in the neighbourhood of this marl seam yielded nothing significant below it, but one or two Crinoid brachials in the 2½ feet of chalk immediately above it and a definite plate of *Uintacrinus* in the next 2 feet. It seems, therefore, that the base of the *Uintacrinus* band may be identifiable with this easily recognizable marl seam, which also marks a substantial lithological change, marl seams continuing to be more or less prevalent well up into the *quadratus* zone. (In this respect the section is markedly parallel with that of Seaford Head.

[1] *Coast Sections*, V, p. 228.

There also the *cor-anguinum* chalk is practically free from seams of marl, which set in 4 feet below the flint line taken by Dr. Rowe as the base of the *Uintacrinus* band,[1] and then continue to occur frequently right up to the *quadratus* zone.)

I was able to trace *Uintacrinus* upwards definitely for 40 feet, and 13 feet higher I found what appeared to be a plate of it. Eight feet higher I found my first plate (a very smooth one) of *Marsupites*, and was able to trace plates of *Marsupites* up to a strong marl seam 52 feet higher. For a further 16 feet I found small and dwarf brachials, with one or two dwarf Crinoid plates, and *Terebratulina Rowei* in abundance. These beds by analogy with the Sussex sections I include in the zone of *Marsupites*. This would give a thickness of 129 feet between the base of the *Uintacrinus* band and the top of the zone of *Marsupites*, of which apparently 53 feet should be definitely assigned to the *Uintacrinus* band, and 68 feet to the zone of *Marsupites*, leaving 8 feet between them of a relationship at present uncertain. These 8 feet I assign for the present to the *Uintacrinus* band in conformity with my treatment of a similar blank area in Hants, thus making a total of 61 feet for the band.

Having fixed my upper limit of the zone of *Marsupites*, the next feature likely to be identified is the incoming of *O. pilula* at the base of the subzone of abundant *O. pilula*. I sought *O. pilula* in vain for 53 feet of chalk, which carried me on to the concrete platform mentioned by Dr. Rowe. There I found *O. pilula* for 10 feet. Then I failed to find it again for 22 feet, which carried me to the edge of the central fall, which entirely obscures, at the foot of the cliff, a thickness of chalk which I made out to be 27 feet, and in which, where accessible in irregular patches higher up, no *O. pilula* was found. The first bed to emerge from the fall on its west side is a foot of chalk between two strong marl seams, and in this bed and for a further 13½ feet *O. pilula* occurred in abundance. The highest beds of this chalk were visible in reefs standing out of the shingle, and it was easy to see that in the highest 2½ feet the Offasters were of the exceptional size characteristic of the top of the zone of *O. pilula* in Hants and Sussex. It therefore seems certain that the zone of *O. pilula* of Hants and Sussex is recognizable in Scratchells Bay with an approximate thickness of 53 feet for the lower subzone and 74 feet for the upper subzone.

Above the zone of *O. pilula* the zone of *Actinocamax quadratus* extended some 200 feet, according to my measurements, to the approximate position of the boundary determined by Dr. Rowe. My measurements are therefore, when summarized—

	feet.
Uintacrinus band	61
Zone of *Marsupites*	68
Zones of *O. pilula* and *A. quadratus*	327
	456

[1] I have found brachials, and perhaps a plate of *Uintacrinus*, between this flint line and the marl seam below it, so making the correspondence perfect.

These measurements compare very curiously with Dr. Rowe's, which were—

	ft.	in.
Uintacrinus band	34	6
Marsupites band (= my zone of *Marsupites*)	47	0
Zone of *A. quadratus* (= my zones of *O. pilula* and *A. quadratus* combined)	343	0
	423	6

It will be seen that our grand totals differ by less than 7 per cent, yet our totals for the *Uintacrinus* band and for the *Marsupites* zone or band differ much more largely, so that it is probable that our lower and upper boundaries of these items are placed in very different positions. Unfortunately Dr. Rowe does not give any indications by which the points at which he fixed these boundaries can be identified in the field, and no close comparison can be made. The same difficulty has repeatedly confronted me in trying to compare my results in Dorset with those obtained by Dr. Rowe, and I have therefore thought it desirable to give in each case summarized sections with sufficient details concerning all indications of boundaries on which I have relied to enable subsequent workers to identify them in the field and use any records of mine which may fill lacunæ in their own. In these sections I have aimed at mentioning every definite marl seam and flint tabular met with, and I believe that with their aid any desired point can be readily picked out. Flint seams are to be assumed to occur at frequent intervals unless otherwise stated.

The following section is intended to serve the above purpose for Scratchells Bay.

EAST END OF *MUCRONATA* FALL AT BEACH LEVEL.

		ft.	in.	ft.	in.
Zone of *B. mucronata.*	Chalk with two marl seams			16	0
	Marl seam marking probably the boundary of the *mucronata* zone fixed by Dr. Rowe.				
Zone of *A. quadratus.*	Chalk	57	0		
	Marl seam.				
	Chalk with a flint tabular	4	0		
	Marl seam.				
	Chalk with a flint tabular	30	0		
	Marl seam.				
	Chalk	36	6		
	Chalk with three marl seams	6	0		
	Chalk	10	6		
	Marl seam.				
	Chalk with a red sponge bed	27	0		
	Marl seam.				
	Chalk with six marl seams	27	0		
	Marl seam.				
	Chalk	1	6		
	Flint seam.				
	Chalk	1	0		
				200	6
	Carried forward			216	6

			ft.	in.	ft.	in.
		Brought forward			216	6
		Marl seam.				
Zone of *O. pilula*.	Subzone of abundant *O. pilula*.	Upper belt of *O. pilula*. — Chalk with *O. pilula* of maximum size	1	6		
		Flint seam.				
		Chalk with *O. pilula* of large size	1	0		
		Marl seam.				
		Chalk with *O. pilula* and three marl seams	11	0		
		Marl seam.				
		Chalk with *O. pilula*	1	0		
					14	6
		Marl seam emerging from fall at base of cliff.				
		Lower belt of *Cinctus* belt of *O. pilula*. — Chalk hidden by fall at base of cliff (about)	27	0		
		Chalk with six marl seams	22	0		
					49	0
		Chalk with *O. pilula*, two marl seams, and two flint tabulars, 3 feet apart			11	0
		Strong marl seam.				
	Subzone of *E. scutatus*, var. *depressus*.	Chalk with a marl seam	4	0		
		Strong marl seam.				
		Flintless chalk, apparently the belt mentioned by Dr. Rowe	5	6		
		Marl seam.				
		Chalk with eight marl seams and two flint tabulars	39	0		
		Strong marl seam.				
		Chalk	4	0		
					52	6
		Strong marl seam.				
	Zone of *Marsupites*.	Chalk with *Terebratulina Rowei* and small Crinoid brachials and plates. — Strong flint tabular.	7	3		
		Strong marl seam.	2	6		
			6	6		
		Very strong marl seam with many fragments of *Inoceramus* just below it.				
		Chalk with *Marsupites* at 6 feet down	12	0		
		Marl seam.				
		Chalk with three marl seams and a thin flint tabular	30	0		
		Very strong marl seam.				
		Chalk	7	0		
		Flint seam.				
		Chalk with marly veins and *Marsupites*	2	6		
					67	9
	Uintacrinus band.	Flint seam.				
		Chalk with marly veins	5	4		
		Flinty chalk	2	3		
		Flint seam.				
		Chalk with *Uintacrinus*	3	3		
		Line of large flints.				
		Chalk with three marl seams	10	0		
		Strong flint seam with what looks like a silicified marl seam just below it.				
		Chalk	2	6		
		Strong marl seam.				
		Chalk	20	0		
		Marl seam.				
		Chalk	9	0		
		Marl seam.				
		Chalk with three marl seams and *Uintacrinus*	9	6		
					61	10
		Marl seam with forking flint tabular 2 ft. 6 in. below it.				
					473	1

The detailed correspondence between the upper belt of *O. pilula* and the chalk immediately above it here and in Hants and Sussex is very striking.

B. *Culver Cliff.*

Not one word too much in dispraise of this exposure of the Chalk between the zones of *Belemnitella mucronata* and *Marsupites* has been said by Dr. Rowe.

The following is a summarized section down from a strong marl seam running along the north side of the ledge which Dr. Rowe took as the lower boundary of the zone of *B. mucronata*:—

	ft.	in.	ft.	in.
Chalk with six marl seams			48	0
Marl seam.				
Chalk			60	0
Marl seam.				
Chalk with one flint tabular and a pair of pseudo-tabulars			107	6
Marl seam.				
Chalk with one marl seam			12	0
Marl seam.				
Chalk with one flint tabular			25	9
Marl seam.				
Chalk			6	9
Marl seam.				
Chalk			48	3
Marl seam.				
Chalk with eight marl seams and three flint tabulars			46	9
Flint seam (lowest in descending series).				
Flintless chalk	2	0		
Marl seam.				
Flintless chalk	5	6		
Nodule bed	1	0		
Marl seam.				
Flintless chalk	2	0		
Marl seam.				
Flintless chalk		6		
Nodule bed	1	0		
Flintless chalk	3	0		
Marl seam.				
Flintless chalk		6		
Nodule bed	2	0		
Flintless chalk	3	0		
Marl seam.				
Flintless chalk	1	6		
Flint tabular.				
Flintless chalk	2	6		
Marl seam.				
Flintless chalk	1	3		
Marl seam.				
Flintless chalk	3	0		
Flint tabular.				
Flintless chalk	2	6		
Marl seam.				
Flintless chalk	2	0		
Marl seam.				
Flintless chalk	1	9		
Marl seam.				
Flintless chalk	1	6		
Nodule bed	1	0		
Flintless chalk	8	3		
			45	9
Carried forward			400	9

Combined zones of *O. pilula* and *A. quadratus*.

	ft.	in.	ft.	in.
Brought forward . .			400	9
Marl seam, approximate upper boundary of the zone of *Marsupites* fixed by Dr. Rowe.				
Flintless chalk	5	0		
Nodule bed	1	0		
Flintless chalk	5	0		
?Nodule bed	1	0		
Flintless chalk	3	0		
			15	0
			415	9

First flint seam of new series.

The figures for the lowest 20 feet are estimates only, the clean surfaces being well out of reach.

It will be observed that my grand total for the combined zones of *O. pilula* and *A. quadratus* is identical with that obtained by Dr. Rowe. So also is it for the flintless chalk, but in this case there is a wide discrepancy between his details and mine, which latter I have therefore given very fully. There appeared to me to be at least five nodule beds, the highest being given by a slip a deceptive appearance of being a continuation of the one just below it, and the bed which I have marked as possibly a nodule bed at the base of the section looked as if it must be either that or a strongly marked sponge bed; it is out of reach, and the point could not be settled.

I have not attempted to apportion this chalk between the zones of *O. pilula* and *A. quadratus*, as I have not yet been able to identify with certainty even the position of the subzone of abundant *O. pilula*, without which the upper boundary of the zone of *O. pilula* can hardly be fixed. As it is undoubtedly present in typical aspect in Sussex to the east, in Hants to the north, and, as we have just seen, in Scratchells Bay to the west, it might be confidently expected to occur here also in typical aspect, if it were not that the chalk succeeding the zone of *Marsupites* here is notoriously abnormal lithologically and that the abnormal lithological conditions may have been accompanied by abnormal palæontological conditions which affected the whole of the zone of *O. pilula*. The most I can say at present is (1) that if the upper boundary of the zone here is of the usual nature it can hardly be reached for 300 feet at any rate from the *mucronata* zone and has to be sought in the remaining 100 feet; and (2) that just by the nodule bed I mark as 2 feet thick I have obtained several Asteroid ossicles, all belonging apparently to a small, gently sloping variety of *Crateraster quinqueloba*, Goldf., which is abundant in the subzone of abundant *O. pilula* in Sussex and is the exact antithesis of the high, large, and steep-sided form which culminates in the subzone of *E. scutatus*, var. *depressus*. There is reason to anticipate that Mr. Spencer will be able to show that such an occurrence has an important bearing on the question which of the subzones is present at this point. As far as I can recollect this is also the point at which in company with Mr. Griffith many years ago I found the *O. pilula* and (much-eroded) Belemnite which are referred to by Mr. Jukes-Browne (*The Cretaceous Rocks of Britain*, vol. iii, p. 93) and Dr. Rowe (*Coast Sections*, V, p. 247).

Dr. Rowe's account hardly does justice to the extraordinary abundance of marl in the flintless chalk. In a thickness of 32 feet there are ten seams, and three of them were noted as being of exceptional thickness.

(*To be continued in our next Number.*)

NOTICES OF MEMOIRS.

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, AUSTRALIA, AUGUST, 1914.

I.—Address to the Geological Section by Professor Sir THOMAS H. HOLLAND, K.C.I.E., D.Sc., F.R.S. (President of Section C).

EXACTLY eighty-three years from the day of our arrival at Sydney, Eduard Suess was born in London.[1] Thus the day, as much as the circumstances of our meeting so far from home, serves to remind us of one who was great enough to recognize the fact that geological evidence from any part of the world has the same value as that obtained in the little continent which has been the most prolific in the products of nomenclature and the most productive in textbooks.

Since the days of Charles Lyell no geologist has been so conspicuously successful in analysing the accumulated mass of evidence, in bringing together the essential facts from all lands, and in compensating for the local excesses of literature. Only those of us who, by long absence from Europe, have felt the full disadvantages of having to express our thoughts in alien terminology can appreciate the real value of Suess's great work. His death since our last meeting makes a conspicuous mark in the history of geological science.

A meeting of the British Association in Australia brings home forcibly to the members of Section C the fact that British Imperial geology is really "the science of the Earth"; partly for this reason one feels inclined to get outside the science and take a survey of some of its suburbs. Not many of them have been left untraversed by my distinguished predecessors in this chair; but there has been of recent years a tendency to avoid the inner Earth, which has rightly been described as "the inalienable playground of the imagination", and consequently, therefore, common land to the geologist as well as the geodesist, physicist, and mathematician.

The geologist who looks below the purely superficial phenomena of the crust is generally regarded as straying beyond his province; but the desire to see the birth-certificate of some of the strange and often unacceptable 'causes' which the mathematical physicist offers us is a pardonable form of curiosity. Our ideas regarding intra-telluric conditions are even proving to be of economic value, one of the most recent and unexpected results of the kind being that just established by Baron von Eötvös in Hungary,[2] whose predictions now bid fair to outstrip those of the 'diviner'! Having noticed the low gravity values over the great cores of rock-salt in the Transylvanian 'Schlier', he finds similar defects of gravity in the same region over certain of the Sarmatian and Pontian domes, which probably owe their shape to subterranean salt-plugs and are now found to be great storehouses of natural gas, which, with or without liquid petroleum, is commonly found with the saline 'Mediterranean' facies of the Upper Tertiary in Eastern Europe. Baron von Eötvös also finds that on the eastern margin of the Great Hungarian Plain, where the younger Tertiary beds are completely concealed by a mantle of alluvium, mud-volcanoes and

[1] See life of Eduard Suess, GEOL. MAG., January, 1913, pp. 1–3, and Portrait, Plate I. His obituary appeared in GEOL. MAG., June, 1914, p. 288.

[2] Comptes Rendus, XVII^{e} Conf. de l'Assoc. Géodés. Internat., Hamburg, 1912, pp. 427, 437.

gas-springs are sometimes found in areas of marked gravity defect, and some of these are now also being drilled for natural gas.

When our ideas of the state of affairs below the surface thus begin to yield economic results, there is hope that they are at last steadying down, becoming more settled, and indeed more 'scientific'. It may not be unprofitable, therefore, to review some of the advances recently made in developing theoretical conceptions regarding the interior of the Earth that are of direct importance to geologists. In undertaking this review I am conscious of the fact that I shall be traversing ground that is generally familiar to all, and much of it the special property of specialists whose views I hesitate to summarize and should not dare to criticize. As the author of the *Ingoldsby Legends* said of the only story that Mrs. Peters would allow her husband to finish, "The subject, I fear me, is not over new, but will remind my friends—

'Of something better they have seen before.'"

The intensity and quantity of polemical literature on scientific problems frequently varies inversely as the number of direct observations on which the discussions are based: the number and variety of theories concerning a subject thus often form a coefficient of our ignorance. Beyond the superficial observations, direct and indirect, made by geologists, not extending below about one two-hundredth of the Earth's radius, we have to trust to the deductions of mathematicians for our ideas regarding the interior of the Earth; and they have provided us successively with every permutation and combination possible of the three physical states of matter—solid, liquid, and gaseous.

Starting, say, two centuries back with the astronomer Halley, geologists were presented with a globe whose shell rotated at a rate different from that of its core. In more recent times this idea has been revived by Capt. (Sir) F. J. Evans (1878) to account for the secular variations in the declination of the magnetic needle.

Clairault's celebrated theorem (1743), on which Laplace based the most long-lived among many cosmogonies, gave us a globe of molten matter surrounded by a solid crust. Hopkins demanded a globe solid to the core, and, though his arguments were considered to be unsound, his conclusions have been revived on other grounds; while the high rigidity of the Earth as a body has been maintained by Lord Kelvin, Sir George Darwin, Professor Newcombe, Dr. Rudski, and especially by the recent observations of Dr. O. Hecker, supplemented by the mathematical reasoning of Professor A. E. H. Love. Hennessy (1886), however, concluded that the astronomical demands could be satisfied by the old-fashioned molten Earth in which the heavier substances conformed to the equatorial belt.

As long ago as 1858 Herbert Spencer suggested that, on account of its temperature being probably above the critical temperature of known elements, the centre of the Earth is possibly gaseous. Late in the seventies Dr. Ritter revived the idea of a gaseous core surrounded by a solid crust, and this was modified in 1900 by the Swedish philosopher, Svante Arrhenius, whose globe with a solid crust, liquid substratum, and gaseous core is now a favourite among some geologists.

Wiechert (1897) supposed that the core of the Earth, some 5,000 kilometres in radius, is composed mostly of iron with a density of 7·8, while this is surrounded by a shell of lithoidal material having a density of about 3·0 to 3·4; and this great contrast in density is about that which distinguishes the iron meteorites generally from those of the stony class. Arrhenius also assumes that iron forms the main part of the central three-quarters, and he shows that this distribution of substance may still be consistent with his theory of a gaseous core: indeed, he not only imagines that the whole of the iron nucleus is gaseous, but also most of the siliceous shell, for he leaves only 5 per cent of the radius as the depth of the solid and liquid shells combined.

But the variety of ideas does not end with theories on the present constitution of the globe. Poisson required the process of solidification to begin from the centre and to progress outwards, while other mathematicians had been happy with the Leibnitzian *consistentior status* as the first external slaggy crust.

Since the days of Laplace all naturalists have been forced to accept the idea of a solar system formed by the cooling and condensation of a spheroidal gaseous nebula; and all except those geologists who have vainly searched for traces of the primeval crust have been happy in this belief.

Recently, however, Dr. F. R. Moulton and Professor T. C. Chamberlin in America have brought together arguments from different points of view to construct the solar system by the aggregation of innumerable small bodies, 'planetesimals,' which have gathered into knots to form the planets. Thus the Earth is supposed to have grown gradually by the accretion of meteoritic matter, and even now, although the process has nearly ceased, it receives much meteoritic material from outside.

With the Chamberlin–Moulton theory there must have been a time when the gravity of the Earth was insufficient to hold an atmosphere of any but the heavier gases, such as carbon dioxide; later, the Earth became heavy enough to retain oxygen, then nitrogen, water-vapour, and helium; while even now it may not be sufficiently attractive to prevent the light and agile molecule of hydrogen from flying off into space. With the growth of the young globe, the compression towards the centre produced heat enough to melt the accumulated fragments of meteoritic matter, and the molten material thus formed welled out at the surface. Such volcanic action is supposed to have predominated at the surface until an appreciable atmosphere was formed, and became charged with water, when the now familiar processes of weathering, erosion, and deposition produced the film of 'rust' which geologists know as sedimentary rocks.

With this last addition to the variegated array of theories about the physical condition of the Earth and about its genealogy, the scientific world began again to settle down into serenity, comforted by the happy feeling that all, at any rate, agree in regarding the Earth as a gradually cooling body, with many millions of years still before it. Then came the discovery of radium, and with it at first an assurance that geologists were justified in claiming a long past, to be followed by a longer future than the most optimistic philosopher had dared before to assume with our apparently limited store of Earth-heat. Now, however, Professor Joly warns us that if the deeper parts of the globe contain anything near the proportion of radio-active bodies found by him in the superficial rocks, we may even be tending in the other direction; that, instead of a peaceful cooling, our descendants may have to face a catastrophic heating; the now inconspicuous little body known as the Earth may indeed yet become famous through the Universe as a new star.[1]

To add to the variety of ideas regarding the present state of the Earth's interior, Professor Schwarz, of Grahamstown,[2] concludes that our volcanic phenomena can be accounted for on the assumption that the main mass of the Earth below a superficial layer is cold and solid throughout, being composed, like the meteorites, largely of unaltered ferromagnesian silicates and iron.

Thus, we see, whole fleets of hypotheses have been launched on this sea of controversy: some of the craft have been decoyed by the cipher-signals of the mathematician; some have foundered after bombardment by the heavy missiles classically reserved for use by militant geologists; others, though built in the dockyard of physicists, have suffered from the spontaneous combustion set up by an inadvertent shipment of radium. Still, some of these hypotheses are yet apparently seaworthy, and it may not be unprofitable to compare them with recently acquired data.

The nearest approach to actual observation with regard to the state of the Earth's interior has been obtained by the seismograph, designed to record the movements of seismic waves at great distances from the disturbing earthquake. Some of the waves sent forth from an earthquake centre travel through the Earth, and some travel around by the superficial crust, the former reaching the distant seismograph before the latter. The seismograph, by its record of

[1] J. Joly, *Radioactivity and Geology*, 1909, pp. 168–72.
[2] E. H. L. Schwarz, *Causal Geology*, 1910.

the waves that travel *through* the Earth, has thus given a certain amount of information regarding the state of the Earth's interior which R. D. Oldham aptly regards as analogous to that given by the spectroscope[1] with regard to the inaccessible atmosphere of the Sun.

The existence of two groups of earthquake waves—those passing through, and those passing near the surface around the Earth—has long been recognized; but R. D. Oldham[2] has shown that the waves passing through the Earth are of two kinds, travelling at two different speeds.

The record on the distant seismograph thus shows three well-marked phases: the first phase, due to waves of compression passing through the Earth's interior; the second phase, due to waves of distortion,[3] also passing through the Earth's interior; and the third phase, recorded by the waves which pass around the arc along the superficial crust.

The third phase is always recorded at a time after the occurrence of the shock proportional to the arcual distance of the recording seismograph from the earthquake centre, the records of several large earthquakes showing an average speed for the waves of about 3 kilometres per second. The rates of propagation of the waves giving the first and second phases are both much greater than of those forming the third phase; and up to an arcual distance of about 120° from the earthquake's centre the rate of their propagation increases with the distance. It is thus assumed that the waves giving rise to the first and second phases in each distant seismographic record, by following approximately along the chord of the arc between the place of origin and the instrument, pass through deeper layers of the Earth when the seismograph is farther away, the material at greater depths being presumably more elastic as well as denser.

But Oldham[4] has shown that when the seismograph is as much as 150° from the earthquake centre there is a remarkable decrease in the mean apparent rate of propagation of the waves giving the second phase in the record, from over 6 to about 4½ kilometres per second. There is also a drop, although not nearly so marked, in the apparent speed of the waves of the first phase when transmitted to a seismograph 150° or more distant from the earthquake origin. Oldham concludes that this decrease of apparent rate for waves travelling through the Earth to places much more than 120° distant is due to their passing into a central core, four-tenths of the radius in thickness, composed of matter which transmits the waves at a markedly slow speed. Thus the earthquake waves which emerge at a distance not greater than 120° from their origin do not enter this central core, while those which pass into the Earth to a greater depth than six-tenths of the radius are supposed to be refracted on entering, and again on leaving the postulated core, in which the rate of transmission of an elastic wave of distortion is very much slower than in the main mass of the Earth around. In consequence of the refraction of these waves on passing through the central core, places situated at about 140° from an earthquake origin should be in partial shadow, due to the great dispersion of the distortional waves, and the few records made so far by seismographs thus situated with regard to great earthquakes show that there is either no, or at most a doubtful, record for the second phase, which is known to be due to the so-called distortional waves.

[1] In his Presidential Address to the Geological Society of London in 1909, Professor W. J. Sollas (Proc. Geol. Soc., 1909, p. lxxxvii) credits H. Benndorf (Mitth. Geol. Ges. Wien, i, p. 336, 1908) with this pretty analogy, but Oldham has the precedence by just two years (cf. Quart. Journ. Geol. Soc., vol. lxii, p. 456, 1906).

[2] Phil. Trans., ser. A, vol. cxciv, pp. 135–74, 1900.

[3] There is more complete agreement regarding the fact that two distinct sets of waves give rise to the so-called preliminary tremors indicated by a seismographic record than about the nature of the waves. Cf. R. D. Oldham, Phil. Trans., loc. cit., and O. Fisher, Proc. Camb. Phil. Soc., vol. xii, pp. 354–61.

[4] Quart. Journ. Geol. Soc., vol. lxii, pp. 456–75, 1906.

Oldham's deductions are based confessedly on a small number of earthquake records—he considered fourteen examples only—but the conclusions based on a small number of trustworthy records, from which variations due to the different methods of marking the phases are eliminated, are more reliable than those for which there are imperfect distant records as well as doubts regarding the exact times of the disturbances. If these observations, however, be confirmed by further records, we are justified in assuming that below the heterogeneous crust there is a thick shell of elastic material, fairly homogeneous to about six-tenths of the radius, surrounding a central core, four-tenths in thickness, which possesses physical properties utterly unlike those of the outer layers; for in this core the 'distortional' waves are either damped completely or are transmitted at very much lower speeds than in the shell.

One cannot consider this interesting inference from the seismographic data without being reminded of the contention of Ritter, Arrhenius, and Wilde regarding the possibility of a persistent gaseous core still above the critical temperature of the substances of which it is composed. According to Ritter,[1] the gaseous core is surrounded by a solid shell. Dr. Wilde[2] postulates the existence of a liquid substratum and a gaseous core within a solid crust, the two outer shells having a thickness that is 'not very considerable'. Arrhenius assumes from purely physical considerations that the solid crust is only about 25 miles thick, that below this it is possibly in a molten condition for about 150 miles, and that the rest is a gas largely composed of iron under a pressure so great that its compressibility is not much less than that of steel.

The whole of these conclusions, being based on assumptions regarding the physical properties of matter under conditions of temperature and pressure that are well beyond those of actual experience, must be put on a plane of science well below that occupied by the investigations initiated by Oldham, who opens up a line of research in which, as said before, the seismograph may justifiably be compared with the spectroscope as an instrument for observing some inaccessible regions of Nature.

The mathematician apparently finds it just as easy to prove that the Earth is solid throughout as to show by extrapolation from known physical values that it must be largely gaseous. As Huxley said in his Presidential Address to the Geological Society in 1869, the mathematical mill is a mill which grinds you stuff of any degree of fineness, but, nevertheless, it can grind only what is put into it; and the seismograph thus offers a new source of substantial grist. Now that it is fairly certain that some of the earthquake waves pass through the deeper parts of the Earth, it is obvious that a fruitful development of science will follow successful efforts to introduce precision in recording, and uniformity of expression in reading, seismographic records.

Oldham[3] has pointed out another way in which analysis of seismographic records may lead to information regarding intra-telluric conditions by comparing the records of waves that pass under the oceanic depressions with those that are sub-continental for the whole or most of their paths. By comparing the records in Europe of the Columbian earthquake of January 31, 1906, with those of the San Francisco quake in the following April, there was a greater interval

[1] A. Ritter, "Untersuchungen über die Höhe der Atmosphäre und die Constitution gasformiger Weltkörper": Wiedemann's *Ann. d. Phys. und Chem.*, vol. v, pp. 405, 543, 1878; vol. vi, p. 135, 1879; vol. vii, p. 304, 1879; vol. viii, p. 157, 1879.

[2] *On the Causes of the Phenomena of Terrestrial Magnetism*, pamphlet, 1890, p. 2. The idea that the Earth's magnetism is due to the electricity generated by the friction between the shell and the core, rotating with a different motion, was suggested by Dr. Wilde in 1902 (Mem. Manch. Lit. Phil. Soc., vol. xlvi, pt. iv, p. 8, 1902). A similar suggestion based also on Halley's conception of a separately rotating inner core was made previously by Capt. (Sir) F. J. Evans in 1878 ("Remarkable Changes in the Earth's Magnetism": *Nature*, vol. xviii, p. 80).

[3] Quart. Journ. Geol. Soc., vol. lxiii, pp. 344–50, 1907.

noticed between the first and second phases of the Californian earthquake—an interval greater than can be accounted for by mere difference of distance between the origin of the shock and the recording instruments. The seismic waves which passed from Columbia to Europe must have travelled under the broadest and deepest part of the North Atlantic basin, while those from California ran under the continent of North America, crossed the North Atlantic not far south of Iceland, and approached Europe from the north-west, the wave paths throughout being under continents or the continental shelf of the North Atlantic. There is thus suggested some difference between the elastic conditions of the sub-oceanic and the sub-continental parts of the crust—a difference which, judging by the particular instances discussed, may extend to a depth of one-quarter of the radius, but is not noticeable in the waves which penetrate to one-third of the radius below the surface.

Obviously these data must be multiplied many times before they can be regarded as a reliable index to a natural law; but it is significant that this indication of a difference between the physical nature of the sub-oceanic and sub-continental parts of the crust is in rough correspondence with the conclusions previously suggested on quite other grounds.

In his Presidential Address to the Geological Section of the British Association at Dover in 1899, the late Sir John Murray drew attention to the chemical differentiation which has been going on between the continents and the oceans since the processes of weathering and denudation commenced. By these processes the more siliceous and specifically lighter constituents are left behind on the continents, while the heavier bases are carried out to the ocean. It is to this process that Professor T. C. Chamberlin[1] also ascribes the origin of the depressions in which the oceanic waters have accumulated. As a corollary of the planetesimal theory, Chamberlin assumes that water began to be forced out of the porous surface blocks of the accumulated meteoritic material when the Earth's radius was between 1,500 and 1,800 miles shorter than it is now; at that time pools of water began to be formed on the surface, and the atmosphere, just commencing its work, began the operation of leaching the heavier bases out of the highlands. Growth of the world proceeded by the infall of planetesimals, and while those meteorites that fell on the highlands became deprived of their soluble bases, those that fell into the young ocean were merely buried unaltered. Thus by the time the Earth reached its present size its crust under the oceanic depressions must have developed a chemical composition differing from that under the continents. According to the deduction suggested by Oldham from the seismographic records, there is a noticeable difference in the sub-oceanic areas to depths of between 1,000 and 1,300 miles—a layer in which the followers of Chamberlin's theory might reasonably expect some physical expression of the partially developed chemical differentiation.

The occurrence of denser material below the ocean has, of course, long been assumed from the deflection of the plumb-line, and was accepted by Pratt for his theory of compensation, as well as by Dutton as a wide expression of the theory of isostasy. Chamberlin[2] thus explains the general prevalence of basic lavas in oceanic volcanoes.

The apparent heterogeneity indicated in the outer shell of the Earth to depths of 1,000 miles is naturally in conflict with the assumption that from 30 miles or so down the materials are in a liquid condition; at any rate, the idea conflicts with Fisher's extreme conception of the liquid substratum, in which the fluidity is supposed to be sufficient for the production of convection currents, upwards beneath the oceanic depressions, spreading horizontally towards the continents, and thence downwards to complete the circuit.

The idea that changes of azimuth and of latitude may be brought about by the sliding of the Earth's crust over its core has been put forward more than

[1] Chamberlin and Salisbury, *Geology*, vol. ii, pp. 106–11, 1906.
[2] *Geology*, vol. ii, p. 120, 1906.

once to account for the climatic changes of past geological ages—the occurrence of temperate or even warm climates on parts of the crust now within the Polar circles, and glacial conditions at the sea-level in countries like India, Australia, Africa, and South America, which are now far from the Polar ice-sheets and in some cases near or within the Tropics. Professor E. Koken, of Tübingen,[1] in an elaborate memoir entitled *Indisches Perm und die Permische Eiszeit*, attributes the idea of a sliding crust to Mr. R. D. Oldham; but a similar suggestion was put forward by the late Sir John Evans twenty years before the publication of Mr. Oldham's paper,[2] and when the theory was restated in more precise form, ten years later,[3] it was subjected to mathematical criticism by J. F. Twisden, E. Hill, and O. Fisher.[4]

Sir John Evans suggested that this movement of the crust was inevitable as a consequence of the moulding of the orographical features and consequent redistribution of weights; but Twisden came to the conclusion that the re-arrangement of the great inequalities on the Earth's surface would be insufficient to produce any appreciable sliding of the order required to make material differences in the climate of any place.

Oldham,[5] who was writing at the time in the field in India and thus away from literature, put forward the idea in 1886 as an independent thought, and made use of Fisher's new theory regarding the existence of a fluid stratum between the solid crust and the supposed solid core to account for the shifting of places relative to the axis of rotation from the equatorial region even to the Polar circles. Oldham drew attention to the recorded small changes of latitude at certain observatories and to the probable changes of azimuth in the Pyramids of Egypt—evidences of a kind which have since been greatly enlarged by the work of Sir Norman Lockyer and others.

The movements assumed to have taken place during the human period are of course small; and to project from them changes as great as the transfer of lands from the Polar circle to the Tropics has the objection that characterizes a surveyor's use of 'unfavourable' triangles in a trigonometrical survey. Before admitting, therefore, that these small changes of latitude and of azimuth may be classed with the palæo-glacialists' evidence as data of the same kind, though so utterly different in magnitude, it is desirable briefly to examine the geological evidence regarding past ice ages in extra-polar areas.

From the records of ancient glaciations we might omit those of the pre-Cambrian rocks of North Ontario and the pre-Upper Cambrian of Norway, as these areas are nearer the Poles than many places which were certainly covered with ice-sheets during the youngest, or often so-called Great, Ice Age. But besides these we have evidence of glaciation in the Cambrian or possibly pre-Cambrian rocks of South Australia at a latitude of 35° or less; in South Africa there were two or more distinct glacial periods before Lower Devonian times in slightly lower latitudes; while in China similar records are found among rocks of the Lower Cambrian, or possibly of older age, at a latitude of 31° N.

The glacial boulder-beds found at the base of our great coal-bearing system in India belong to the same stratigraphical horizon as the glacial beds found in South Africa, certain parts of Australia, and in parts of Brazil and São Paulo near or within the Southern Tropic.

[1] *N. Jahrb. für Min. u.s.w.*, p. 537, 1907.

[2] J. Evans, "On a possible Geological Cause of Changes in the Position of the Axis of the Earth's Crust": Proc. Roy. Soc., vol. xv, p. 46, 1866.

[3] J. Evans, Presidential Address, Proc. Geol. Soc., 1876, p. 105.

[4] J. F. Twisden, "On possible Displacements of the Earth's Axis of figure produced by Elevations and Depressions of her Surface": Quart. Journ. Geol. Soc., vol. xxxiv, p. 35, 1877. E. Hill, "On the possibility of Changes in the Earth's Axis": GEOL. MAG., 1878, pp. 262, 479. O. Fisher, "On the possibility of Changes in the Latitude of Places on the Earth's Surface": GEOL. MAG., 1878, pp. 291, 551.

[5] GEOL. MAG., 1886, p. 304.

These glacial beds are often referred to in the geological literature as Permo-Carboniferous in age; but Professor Koken regarded the formation in India as Permian. Other valuations of palæontological evidence, similar to that relied on by Professor Koken, place these beds at a distinctly lower horizon in the European stratigraphical scale, and recent work by officers of the Geological Survey of India in Kashmir tends to confirm this latter view; we now regard the base of our great coal-bearing system in India—the horizon of the glacial boulder-beds—as not much, if at all, younger than the Upper Coal-measures of Britain.[1] The precise age of the horizon is not very important for our present consideration: the important point is that in or near Upper Carboniferous times a widespread glaciation occurred throughout the area now occupied by India, Australia, and South Africa. The records of this great glaciation are thus found stretching northwards beyond the northern as well as southwards beyond the Southern Tropic.

Now, on the assumption that the cold climate in this region was due to a movement of the crust over the nucleus, Professor Koken has produced an elaborate map of the world, showing the distribution of land and sea during the period, with the directions of ocean currents and of ice-sheets. The Permian South Pole he places at the point of intersection of the present 20th parallel S. and 80th meridian E.—that is, at a point in the Indian Ocean about equidistant from the glaciated regions of India, Australia, and South Africa. The Permian North Pole is thus forced to take up its position in the centre of Mexico, while the Equator strikes through Russia, Italy, West Africa, down through the South Atlantic and round by Fiji to Vladivostock.

The very precision of this map reduces the theory on which it is based to a condition of unstable equilibrium. If glacial conditions were developed in India, Australia, and South Africa by a 70° movement of the crust, were the movements to and from its assumed position in Permian times so rapid that the glaciation of these widely separated areas appear to be geologically contemporaneous? If such movements had occurred, instead of evidences of glaciation over a wide area at the *same* period, we ought rather to find that the glaciation in each of the widely separated points occurred during distinctly *different* geological periods.

But that is not the only weak spot in the evidence. The Permian (or Permo-Carboniferous) glaciation of Australia took place on the east and south-east of the continent as well as in Western Australia, and the eastern ice-sheets would thus have been active within 30° of Professor Koken's Permian equator. There are still three other serious pieces of colour-discord in this picture. In the State of São Paulo—that is, within Koken's 'Permian' tropics—Dr. Orville Derby has described beds which strikingly recall the features of the Upper Palæozoic glacial beds of India and South Africa. It is possible that these are due to the work of glaciers at a high level; but, since the publication of Professor Koken's memoir, other occurrences of the kind have been described by Dr. I. C. White in different parts of Brazil, and there is a general correspondence between the phenomena in South America and those in the formations of the same age in the Indian, Australian, and African regions.

Then, too, if we accept this expression of the physical geography during Upper Palæozoic times, we must carefully explain away the suspicious breccias and brockrams which have been regarded by many geologists as evidences of a cold climate during Permian times in the Urals, the Thüringerwald, the English Midland and Northern counties, Devonshire and Armagh—places that would lie on or near Koken's 'Permian' equator. Finally, we find the hypothetical Permian North Pole in a locality which has failed to produce any signs of glaciation.

(*To be concluded in the October Number.*)

[1] H. H. Hayden, Rec. Geol. Surv. Ind., vol. xxxvi, p. 23, 1907.

II.—*Papers read in Section C (Geology), Meeting of British Association, Australia, August, 1914.*

(1) Deserts (Definition, Causes, and Soils). By Professor J. W. Gregory, F.R.S.

THE term 'desert', according to modern usage, means a country which is unoccupied in consequence of having an arid climate. Various exact limits of the conditions that established deserts have been proposed. Thus Sir John Murray adopted the desert limit as a 10 in. rainfall, and William Macdonald (*Dry Farming*, p. 91, 1911) that of 20 inches as the limit of the arid region. Goodchild, on the other hand, rejected numerical limits as arbitrary and impracticable, and proposed a more elastic definition based upon a general deficiency of moisture. Walther has pointed out that deserts cannot be precisely defined on biological, morphological, or climatic grounds.

The factors that control the development of desert are not only climatic. The geological structure of the district has an important influence. The presence of rocks which are very permeable owing to porosity of jointing, and which crumble into coarse grains, contributes to desert conditions. Geographical situation is also important, for a plateau which has a free drainage to adjacent lowlands is more easily converted into desert than an area with no easy escape for its subterranean water.

The climatic influence depends not only upon the total amount of rainfall but upon its distribution through the year. Thus a country where the rainfall is in the late summer and autumn may be economically desert, whereas the same rainfall at a more suitable season would render the country fertile. The Transvaal, for example, is hampered by its only certain rains falling between November and March. Temperature and the complex group of factors which determine the rate of evaporation also have an important influence.

Hence the development of desert is not determined by any rigid minimum of rainfall, but by the balance between the many conditions which govern the utilization of the rain.

Deserts are most easily produced and least curable where the rainfall is low, the temperature is high, the wind is strong, and the country consists of a plateau where there is an easy drainage to the adjacent lowlands. On a high plateau the elevation, by lowering the temperature and cooling the air uplifted on to it, tends to secure rain, though if it easily drains to the lowlands the main value of the rain may be on them.

Proximity to the sea is quite consistent with a desert development, for if the sea-water be colder than the land, the capacity of the air for moisture is increased as it blows ashore and a sea-wind may therefore act as a drying and not as a moisture-carrying agent.

Desert and non-desert conditions have frequently alternated in the same district. Thus in the British area there is evidence that desert conditions prevailed during the times of the Torridon Sandstone, the Old Red Sandstone, the Permian, the Trias, and there is evidence of an arid climate in Ireland during part of the Lower Kainozoic. It has

been suggested that the existing deserts are now increasing, but the evidence (recently summarized in the *Geographical Journal*, vol. xliii, pp. 148–72, 293–318, 1914) indicates that there has been no general expansion of the desert areas, which are, however, in some places shifting their positions in consequence of local climatic changes.

Deserts are not absolutely incurable, and, owing to a better knowledge of how to use their slight and irregular rainfall, many once-desert areas are now in profitable occupation. When suitably watered, deserts may be extremely prolific; for their soils are often rich in immediately available plant-foods which have accumulated during the long period of rest. The desert soils are often very deep and their crops are nourished from an unusually thick layer. The desert soils especially accumulate salts of potash and lime, which would be leached out of them with a heavier rainfall.

Australian soils have as a rule less than the usually accepted minimum of phosphoric acid required for cultivability. Thus, according to the analyses collected by Professor Cherry, English soils have ·098 per cent of phosphoric acid, American ordinary soils ·116, and American clay soils ·207; yet the heavier soils of Victoria have only ·06 and the light soils of the mallee only ·047.

Professor Cherry's results are confirmed by a varied series of 267 soil analyses from Germany, Holland, Spain, Hungary, Jersey, Sweden, Russia, Java, Sumatra, India, Sandwich Isles, the Congo, the Cameroons, Senegambia, German East Africa, South Africa, and Madagascar. The number includes 22 British and 57 from various outlying parts of the United States of America. In these 267 analyses the average of phosphoric acid is ·157 per cent.

Most soils contain more phosphoric acid in the soil than in the subsoil—an advantage which Australian soils do not share. A series of 220 analyses, collected for me by my assistant, Mr. P. Brough, which show the composition of various soils and their subsoils, give an average of ·158 of phosphoric acid in the soil and ·135 in the subsoil; and, excluding a couple of subsoils in which the result is so high that there must be an inclusion of some phosphatic fragment, the ratio of phosphoric acid in soil to subsoil is 16 to 13. In some cases the soil may owe its excess of phosphoric acid to manure; but the excess is often shown in cases in which the land has not been manured.

This series of analyses confirms the generally accepted fact that Australian soils are exceptionally low in phosphate and that outside Australia the soil is usually more phosphatic than the subsoil.

The only explanation of these two abnormal features of Australian soils that appears at all satisfactory is that proposed by Professor Cherry; according to his interpretation the phosphatic accumulation in the soil is due to the action of mammals, and owing to the poverty of Australia in mammalian life no such phosphatic enrichment of the soil has taken place. Soils, therefore, in Australia, which appear to be incurably barren, may, owing to their other excellent qualities, prove of high value if their poverty in phosphoric acid be remedied by manure.

(2) Note on the Occurrence of Loess Deposits in Egypt and its Bearing on Change of Climate in Recent Geological Times.[1] By H. T. Ferrar, M.A., F.G.S.

At a recent meeting of the Association Dr. Hume and Mr. Craig submitted the view that there had been no change, except that of gradual desiccation, in recent geological times in Egypt. Since their paper was published, evidence that the change of climate has not been uniform has been recorded from neighbouring countries. The following short paper is intended to show how Æolian desertic deposits may be interstratified between freshwater beds without any change of climate.

In the northern delta of Egypt are great stretches of flat land a few feet above sea-level. These areas are covered by ordinary Nile alluvium and remain damp during the winter months but dry in summer. Owing to the evaporation which takes place during the spring and early summer, soluble salts accumulate at or near the surface of the soil, rendering it incoherent and powdery. Winds are now able to lift and transport this material until it is arrested by the roots of halophyte plants or other obstacles. Here also are deposited the dead shells of helices, and occasionally also the remains of land animals, such as the jackal, rat, bird, lizard, or snake, which have been seen frequenting dust-dune areas. In fact, the dust dunes of Northern Egypt, known as Kardud to the inhabitants, are local deposits of Loess.

A depression of the land of only a few feet, and such as that which has taken place since Roman times in Egypt, would cause another fluviatile layer containing the common shell *Cyrena fluminalis* or a lacustrine bed to be superimposed upon them. It is thus manifest that a desertic deposit interstratified between two freshwater beds is not necessarily a proof of change of climate.

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(3) The Physiography of Arid Lands (as illustrated by Desert Egypt). By W. F. Hume, D.Sc., F.R.S.E., A.R.S.M., Director Geological Survey of Egypt.

The characters of an arid land cannot be separated from its past history, and in Egypt five physiographic features of first importance have to be considered. These are—

1. A belt of deep impressions in the extreme west, the famous Oases.

2. The broad waterless expanse of the Western or Libyan Desert, to the west of the Nile, and the corresponding limestone plateau region (the Maaza Limestone Plateau) to the east of the river.

3. The Nile Valley with its Delta.

4. The Wilderness of the Red Sea Hills and Sinai with its rugged mountains and tortuous valleys.

5. The Red Sea and its narrow prolongations, the Gulfs of Suez and Aquaba, together with the coastal plains.

Each of these divisions requires separate treatment. The paper

[1] By permission of the Director-General of the Egyptian Survey Department.

gives a rapid sketch of the geological history of Egypt as known to us at present, the formation of the ancient core of pre-Cambrian or Palæozoic sediments, volcanic rocks with invasion by granitic magmas, the brief Carboniferous marine advance, and later the much more important Jurassic-Cretaceous transgression, which practically affected almost the whole of Egypt, giving rise to the Nubian Sandstone and the important phosphate-bearing Cretaceous Series. The Eocene strata which form the major portion of Central Egypt are probably formed, at the base, of remade Cretaceous material, and only in their upper portions show marked evidence that the underlying sandstones and igneous rocks are undergoing erosion.

The re-arranging of Cretaceous strata eroded during Eocene times is regarded by the writer as explaining the great difficulty experienced in drawing a lithological line of unconformity between the beds of these respective periods, though the faunal differences indicate the great break between them.

Fringing the pre-Eocene and Eocene areas of Egypt are a series of Miocene and more recent formations which are of great interest both from tectonic and economic points of view.

In considering the separate physiographic features it is pointed out:

1. In the formation of the Oases it is necessary to consider the denudation of the area by marine erosion while rising from the sea and the effects of former more humid climatic conditions. Where the Nubian Sandstone or other soft beds have been exposed, as Beadnell has pointed out, the Oases depression without outlet is produced by wearing through wind-blown sand.

2. The Great Plains of the Libyan Desert are regions of low dip, of meagre rainfall, and thus wind is the dominant factor. A sandy region to the north supplies the sand necessary for erosion. The character of the desert surface depends on the nature of the geological strata present. The undulating gravel plateaux, or *serir*, the limestone expanse, the 'melon' country, and the fossil floors are various forms in which the desert presents itself, the main feature being the removal of all particles capable of being transported by wind. These are deposited as sand-falls in the wind-shadows of the Nile Valley scarp or other depressions. The sand dunes which are locally developed are in sharp contrast to the main desert, these probably depending on three main factors—the existence of sandy deposits determining their source of origin, the usual direction of the wind their trend, and the relief of the ground their position.

The Maaza Limestone Region is similar to the Libyan Desert, but has a greater rainfall. It thus presents a fine example of the effects when rain acts during short periods on rock-surfaces affected by temperature variations. Deep ravines, remarkable water-holes, caverns, natural bridges, and surface coloration films due to the trickling down of ferruginous solutions over cliff-walls are among the prevailing features in the southern part of this area.

3. The present course of the Nile Valley appears to depend on three factors: (1) the formation of the syncline, the axis of which it partly follows; (2) the erosion of the softer strata along their outcrops determining the present north–south trend of the major courses

of the river; and (3) the possible effect of the rotation of the earth (Van Baer's law), the stream tending to hug its eastern bank. Attention is called to the region of exceptional erosion where heavy masses of Eocene limestone rest on and have slipped over the subjacent soft Cretaceous marls and slates. These slips must have been connected with greater rainfall and earth-movement as widespread terraces extend in front of the main cliff and rise to some 110 metres above the present river-level. The triple terracing of the Nile is briefly considered.

4. The Mountain Region of the Eastern Desert is essentially an Anticlinal Area, where tension is in excess of compression. The differential movements are considerable, minor folds play a conspicuous part, and great fractures determine earth-features of considerable magnitude. The result is that the masses of granite and metamorphic rocks hidden beneath the surface in Central Egypt are here exposed by denudation, forming the Red Sea Hills and Sinai Mountains.

The different geological formations give rise to very varied surface features. Attention is called to the importance of rain as a sculpturing agent. The soft Nubian Sandstone is easily eroded both by wind-borne sand and water, giving rise to conspicuous depressions. In the Granitic areas temperature variation breaks up the solid rock, huge domes are produced by flaking off of concentric shells. Dykes give rise to marked differences in surface outline, the harder quartz-porphyries determining the form and general trend of many of the mountain summits, while the softer diabases, being easily eroded, give rise to gullies seaming the precipitous sides of the granitic hills. The general character of the country where schists and volcanic rocks are present is also described.

5. In the Gulf of Suez area another factor has come into play. Here sea-arms project far inland between land-surfaces subject to desert conditions, and their waters become centres of far-reaching chemical activity. Thus coral-reefs are changed to dolomites, sea-shells of carbonate of lime to gypsum, hydro-carbons are in quantities of economic importance, and mineralized areas of lead and zinc ores, of manganese oxide, of iron pyrites, and of sulphur are present in the young Tertiary beds which fill these Red Sea depressions. From Suez to beyond Halaib, that is, throughout the length of Egypt, gypsum forms a conspicuous fringe between the ancient hills and the sea, generally dipping gently seaward on the borders of the Red Sea itself. Further north, in the Gulf of Suez area, the conditions are more complicated. Dyapir, or piercing folds such as have been described by Professor Mrazec in Roumania, are of common occurrence, and there is remarkable interplay between the hard and soft members of the folded series.

The surface structure of an arid land is not only the direct reflex of its geological structure, but also of former climatic change. Many factors in Egypt point to great rainfall in the past, such as gravels of igneous material in the Nile Valley far from their source of origin, masses of travertine in the Oases, the varying terraces of the Nile Valley itself, the evidence of expansive lakes at Kom Ombo, etc.

Though the main features of a desert land depend on the geological structure and in part on past climatic conditions, there are characteristics which are typical of all arid regions. These are far removed from the great marine areas and from the zone of rainfall dependent upon solar activity in lands beneath the Tropics.

These typical desert features have already been referred to, and include—

1. The sweeping of all fine material from the surfaces of the plains by the action of the wind, and formation of plateau summits.
2. Intense scouring of these surfaces by wind-driven sand.
3. The breaking up of the most solid rocks by temperature variation.
4. The formation of sand dunes behind obstructions or where the relief of the ground favours their development.
5. The formation of mushroom-shaped pillars, or standing-out of harder materials on bases undercut by the sand.
6. The formation of sand-worn pebbles of typical angular outlines, the well-known Dreikante.
7. Vermicular markings on limestones, due it may be to etching during the movement of evaporating saline solutions.
8. Formation of desert-crusts by leaching out of the soluble materials contained in the rocks, with evaporation at the surface, resulting in deposition of the oxides of iron and manganese. Mr. Lucas, Director of the Survey Department Laboratory, has made a special study of these desert and river films, the latter probably only differing from desert ones in degree.
9. Flaking off of surfaces in the surface zone affected by temperature variation. Also fracture due to the same cause. Fragments of porphyry, limestone, etc., are often split into a series of parallel flakes standing vertically, their original connexion to one another being clearly indicated by their close juxtaposition.

In the half-desert where rain, though brief, is intensely active while it lasts, a series of interesting phenomena are presented: deep cañon-like valleys, boulder-strewn gullies, saw-back ridges, parallel-dyke country, saline marshes, dry waterfalls or steep precipices in the valley-floors, great talus-slopes.

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(4) The Denudation of Arid Regions by Wind and Water. By Johannes Walther, Professor of Geology and Palæontology in the University of Halle, Germany.

EVERY climatic region is characterized by a different type of disintegration and denudation of soft or softened rock by the agents of erosion. In the nival region a cover of snow protects the surface of the earth during a long period of the year.

In the humid zone and also in the equatorial pluvial region the soil is overgrown by a network of roots and rootlets of millions of plants, which bind together the small particles and protect them against wind and running water.

In arid regions, where the rain is not sufficient to form perennial rivers, and where the vegetation forms isolated patches in the barren country, every particle of soft or disintegrated rock is quickly taken

away by the wind or the occasional rainfall. Therefore the general denudation of the land is very powerful. The Egyptian monuments, exposed during 4,000 years to the disintegrating and denuding powers of the desert, offer beautiful examples of the different kinds of dry disintegration, and many of them show very clearly also the transporting effect of the wind.

REVIEWS.

I. — W. W. Nikitin. La Méthode Universelle de Fedoroff. Traduction française par L. Duparc and Mlle V. de Dervies. Two volumes in one; pp. 516 and atlas. Genève, Edition Atar; Paris, Béranger. 30 francs.

THE universal or theodolite methods of investigating the geometrical and optical properties of crystals were first fully described by Professor Fedoroff in the year 1893. The problems connected with the geometrical study are relatively simple, and the original theodolite or two-circle goniometer scarcely admitted of any essential improvement. On the other hand, the full determination of the more important optical constants of a crystal fragment or of a mineral in thin section obviously presents difficulties of a far higher order, which have only been successfully surmounted after the expenditure of much time and ingenuity on the part of the creator of the method and of his pupils, amongst whom the author of the present work must always take the highest place. The employment of the Fedoroff universal stage in its present perfected form cannot fail to revolutionize the optical study of crystals, not merely by reason of the fact that a mineral can be identified with great rapidity, but because it is now possible to determine optical constants with such a high degree of exactitude as to settle within narrow limits the position of the mineral in its isomorphous group. This is especially true of the felspars, the optical data of which have been so extensively and carefully studied.

The work is a translation with many important additions of a comprehensive guide to the use of the universal stage, which was especially written by Professor Nikitin for the use of the students in the St. Petersburg School of Mines. Its scope may be best indicated by the following table of contents:—

Tome i: Introductory chapter on the optical properties of crystals, pp. 1–59. Graphical methods, especially those relating to the use of the Fedoroff stereographic net, pp. 60–91. Description of the universal stage and its adjustment on the polarizing microscope, pp. 92–120. Discrimination of optically isotropic, uniaxial, and biaxial crystals, pp. 121–39. Determinations of the orientation and optic axial angle of a biaxial crystal, pp. 140–89. Approximate determination of the refractive index, 190–237. Recapitulation of methods for a biaxial crystal, pp. 238–49. Uniaxial crystals, pp. 250–69.

Tome ii: Determination of the thickness of the section and of the birefringence, pp. 275–443. Determination by extinction methods of

the value of the optic axial angle in cases where the optic axes are inaccessible, pp. 444–86. Birefringence of uniaxial minerals, pp. 487–514.

The atlas contains eight plates, and includes a copy of the well-known stereographic net, as well as several ingenious graphical methods of reducing the observations.

The book contains much original matter which has never hitherto been published in a West European language, and attention may be especially called to the new Nikitin method of determining refractive indices by means of total reflection (pp. 214–37).

With regard to the exposition of the subject-matter, it may be stated that the book shows unmistakable evidence that the author has had great teaching experience and fully realizes which portions are likely to require more detailed treatment. The result is a work which can be confidently recommended to all who desire to avail themselves of the most modern methods of optical study, whether they be petrologists, mineralogists, or chemical crystallographers. Concerning the translation and editing, it need only be said that the high standard for which French writers are justly celebrated is fully maintained.

II.—Catalogue of Scientific Papers, Fourth Series (1884–1900). Compiled by the Royal Society of London. Vol. XIII, A–B. pp. xcviii, 951. Cambridge: University Press, 1914 (July). Price £2 10*s*.

WE lose no time in announcing the publication of this volume, which concludes for A and B the one hundred years Catalogue of Scientific Papers undertaken by the Royal Society, the first volume of which appeared in 1867. As a great part of the literature included in this series has never before been accessible in any catalogue, we have waited somewhat impatiently for its appearance. So far as one can judge by a hasty glance through the volume, and an intimate knowledge of the method of compilation, this series shows a marked improvement on those preceding, especially in the attempt to secure a more complete inclusion of serials and their contents, and intelligent specification of authors' names. Of the multitude of papers written it is enough to say that 63,271 titles are included, and the preface admits that "brief notes . . . have not been catalogued owing to inevitable limitations of space". The value of such can only be determined by the worker, to whom in many cases a few lines may be more important than a monograph. We much regret that the University Press have felt obliged to print in so small a type and in so close a form, and think that the insertion of a rule between each entry would have been a great advantage to the reader and to those institutions which have cut up and carded the previous volumes. The spacing suggested would, it is true, have extended to perhaps 150 extra pages, but the advantages would have outweighed the disadvantages considerably; and one would quite as soon pay £3 as £2 10*s*. for the volume, so the matter of price cannot have been the reason, any more than considerations of space, which would not have been more than 6 inches of shelving extra for the series. We are

glad to be rid of the numbering of the entries, a troublesome and annoying business to compilers, and a useless thing to readers in such a work. We thank the Cambridge Press for coming to the rescue of the Royal Society and giving us this volume, and we congratulate the Royal Society on the assurance that its great undertaking is now secure to a conclusion.

III.—Economic Geology. By Charles H. Richardson. 8vo; pp. 320, ix, with 133 figures in the text. New York and London: McGraw-Hill Book Company, 1913.

LIKE many textbooks, Professor Richardson's *Economic Geology* has emanated from a series of lectures given to students from year to year. The lectures on which this book is based were commenced some twenty years ago, so that the author is fully justified in now giving them to a wider circle of students. The book deals only with metals and their ores, but the author promises a companion volume on non-metallic minerals, a textbook for which there must be considerable demand.

The treatment of the subject is methodical and simple. Metals are classified as precious, useful, and rare; the 'useful metals' are taken in the order of their chemical separation. Under each metal are considered its properties, ores, origin and distribution of ores, method of extraction and uses. Special chapters deal with the classification and origin of ore deposits, and there is a final chapter giving statistical information.

The work is furnished with an excellent index and is illustrated by 133 photographs and diagrams, carefully chosen from the best books on ore deposits.

W. C. S.

IV.—Canada: Department of Mines. Geological Survey Guide-books. Ottawa: Government Printing Bureau, 1913.

THESE Guide-books were prepared for the use of members of the Twelfth International Geological Congress. They contain a large amount of information relating to the geology and physiography of the various areas visited by members of the Congress.

There is a general introduction to each excursion, followed by a fuller treatment of the country surrounding the special centres of observation, which is copiously illustrated with maps, sections, and photographs. Notes are also given in explanation of the features of the country seen *en route*.

Space does not permit of even a cursory survey of the valuable matter in these little books; it must suffice to give a bare list of contents.

No. 1 (2 parts). Excursion in Eastern Quebec and the Maritime Provinces. (A useful general geological map of Canada, on the scale of 100 miles to an inch, is included.)

No. 2. Excursions in the Eastern Townships of Quebec and the Eastern part of Ontario:—

The Haliburton–Bancroft area of Central Ontario.

Asbestos Deposits of the Province of Quebec.

Mineral Deposits near Kingston, Ontario.

No. 3. Excursions in the neighbourhood of Montreal and Ottawa:—
The Morin Anorthosite Area.
The Monteregian Hills.
Mineral Deposits of the Ottawa District.
Pleistocene—Montreal, Covey Hill, and Ottawa.
Ordovician—Montreal and Ottawa.
No. 4. Excursions in South-Western Ontario:—
Niagara—Iroquois Beach.
The Palæontology of the Guelph, Onondaga, and Hamilton Formations of Western Ontario.
The Palæozoic Section at Hamilton, Ontario.
No. 5. Excursions in the Western Peninsula of Ontario and Manitoulin Island:—
Silurian Section at the Forks of the Credit River.
Ordovician Section on Credit River, near Streetsville.
Algonquin Beach, Glacial Phenomena and Lowville Limestone in Lake Simcoe District, Ontario.
Geology of selected areas on Lakes Huron and Erie in the Province of Ontario.
No. 8 (3 parts). Transcontinental Excursion (Toronto to Victoria and return via Canadian Pacific and Canadian Northern Railways).
No. 9. Transcontinental Excursion (Toronto to Victoria and return via Canadian Pacific, Grand Trunk Pacific, and National Transcontinental Railways).
No. 10. Excursions in Northern British Columbia and Yukon Territory and along the North Pacific Coast:—
Prince Rupert and Skeena River.
Yukon and Malaspina.

It will be seen that the territory covered is very extensive, and in fact there are very few areas of geological interest in the Dominion to which one cannot find some reference in these books.

These guide-books will prove invaluable to tourists and also to prospectors and emigrants having some acquaintance with geology and seeking fuller information of the Dominion.

V.—Hudson Bay Exploring Expedition, 1912. By J. B. Tyrrell. Twenty-second Report of the Ontario Bureau of Mines, 1913.

THE author describes his journey down the Nelson River from Lake Winnipeg to its junction with the Echimamish, up this river to its head, across the narrow rocky divide which bounds the waters of the Nelson River on the east and then down the Hayes River to York Factory on Hudson Bay.

The Hayes River was surveyed by Professor Stewart, of Toronto, from its junction with the Shamattawa River to its mouth, a distance of 60 miles, while the author made a short expedition up the Shamattawa and also explored the country in the neighbourhood of York Factory.

On the return journey passage was taken to Fort Severn at the mouth of the Severn River, which was ascended in canoes for a distance of 56 miles to the mouth of Fawn River. This river was then ascended for 180 miles to Trout Lake, from which point the route lay southward to Cat Lake, on the waters of the Albany River, passing a number of important lakes on the way.

The general description of the district thus traversed is of much interest. The highest ground consists of a rocky granitic plateau with an elevation of 1,500 feet above the sea in North latitude 52°, West longitude 92°, and from here northwards the ground slopes gradually to Trout Lake, which lies near the northern boundary of the broken country. From Trout Lake northward to Hudson Bay the slope continues at about the same rate, but the rock soon disappears under glacial and post-glacial deposits, and the country is then covered with an even mantle of glacial clay or till, upon which marine sands and clays are often found to rest ; much of the country is flat and occupied by extensive peat bogs.

The geology is discussed under the heads of the different formations: Archæan, composed of granites, gneisses, and other igneous or highly altered sedimentary rocks; Palæozoic, including Ordovician and Silurian limestones and dolomites extending for 60 miles southwards from Hudson Bay; and Pleistocene.

Notes are given on the various exposures and descriptive lists of the Ordovician and Silurian fossils collected. The glaciation is dealt with in some detail, and the different directions of movement of the ice are discussed.

VI.—Geological Surveys.

(1) Portugal. Comunicacões da Comissão do Serviço Geológico de Portugal. Tom. ix, pp. 288, xxiv. Lisbon, 1912–13.

THIS volume includes three papers on the petrology of Portugal by V. Souza-Brandao; also notes (with a tabular analysis) on the organization of the Geological Surveys of Europe. In addition to the papers in Portuguese there are several interesting communications which have been written in French in order to give them the wider circulation which they deserve.

A paper by P. Pruvost records the discovery of fossils in the *schistes à Nereites* of San-Domingos. These beds were described by Delgado and were correlated with the *Nereitenschichten* of Thuringia, which are of Middle Devonian age. The fossils now discovered comprise Brachiopods and Trilobites and include *Clymenia lævigata*, a fauna which places the beds in the Famennian stage of the Upper Devonian.

J. Lambert contributes a description of ten species of echinoids from the Callovian of Cesaréda. Both this and the paper mentioned above are illustrated by excellent plates.

In addition to reports on economic geology, Paul Choffat has published the ninth of a series of biographies of Portuguese geologists—Baron Wilhelm Ludwig von Eschwege (1777–1855). The paper gives a complete résumé of Eschwege's writings and a most interesting account of his efforts to promote the mining industry in Portugal during a most disturbed period of its history.

The tenth series of the "Geological Bibliography of Portugal and its Colonies (1910–12)" contains notices of 154 publications and gives brief analyses of the more important papers.

W. C. S.

(2) United States of America.—The geology of Alaska is the subject of a brief review in a previous number of this journal (Geol. Mag., 1914, p. 31), in which six bulletins relating to this territory were noticed. Since then we have received three additional bulletins, Nos. 536, 538, and 542, dealing with the geology of parts of Alaska.

No. 536. The Noatak–Kobuk Region, Alaska. By Philip S Smith, 1913.—This deals with the geology of the basins of the Kobuk and Noatak Rivers, which drain into Kotzebue Sound. The shores of this part of Alaska were visited by Sir John Franklin in 1826 and by many other Arctic explorers. Having regard to the great difficulty of exploration in this country, the maps produced are extraordinarily complete. Large areas still remain unexplored, but food and fuel are scarce and there seems small prospect of developing any mineral occurrences. A large area is occupied by metamorphosed sediments, possibly Palæozoic, and by Palæozoic limestones, including some beds of Silurian and Devonian age. Carboniferous sandstones and limestones have yielded fossils of Mississippian age. The igneous rocks include altered basalts, in part contemporaneous with Palæozoic limestones; rocks of andesitic and dioritic composition are associated with Lower Cretaceous or Jurassic rocks, and are cut by granitic intrusions and basaltic rocks of late Tertiary age.

No. 538. A Geological Reconnaissance of the Circle Quadrangle, Alaska. By L. M. Prindle, 1913.—The area mapped is situated in the Yukon–Tanana region. Here again there are large areas of Palæozoic sediments, those of pre-Ordovician age being highly metamorphosed. Jurassic and Triassic rocks appear to be absent. Diabase and basalt are associated with the Palæozoic rock, and there are large intrusions of biotite-granite of Mesozoic age. The youngest igneous rocks are late Cretaceous or early Tertiary, and consist of rhyolites, dacites, and basalts.

No. 542. Mineral Resources of Alaska: Report of Progress of Investigations in 1912. By A. H. Brooks and others, 1913.—This is the ninth of a series of bulletins giving preliminary reports on deposits of economic interest and a summary of the mining industry in 1912.

The "Bibliography of North American Geology of 1912, with subject index", by John M. Nickles, 1913 (Bulletin 545), includes all publications bearing on the geology of North America and the adjoining islands, also of Panama and the Hawaiian Islands. It follows the plan of similar bibliographies published annually since 1906.

Other bulletins received are Nos. 531 and 539, both of which are restricted to information having a purely economic bearing.

(3) Alabama Geological Survey.—We have received Bulletins 13 and 14, being the statistics of the mineral production of Alabama for 1911 and 1912, compiled from the *Mineral Resources of the United States*, by C. A. Abele. The Geological Survey has also issued a third edition of *Iron Making in Alabama*, by Dr. W. B. Phillips, the earlier editions of which were published in 1896 and 1898.

CORRESPONDENCE.

THE GEOLOGICAL SOCIETY'S ABSTRACTS.

Sir,—I have received a letter from the Society stating that it is unusual for Fellows resident abroad to receive the "Abstracts of Proceedings". These publications, with notices of the papers and reports of the discussions, are probably taken as a matter of course by most Fellows in the British Isles, while they may be scarcely known to those elected while in residence abroad. They provide information months earlier, and often contain matter that is not given at all in the "Quarterly Journal". It is easy to give a number of instances where papers have been read and discussed, and the larger publication, when it at last arrives, has only a bare statement of the title. Apart from the value of the account of what the author said, the reports of the discussions are often of the greatest interest to those unable to be present at the meetings. The abstracts promote the objects of the Society by stimulating interest in its larger publications, the contents of which are already familiar in outline on arrival. They are not then put aside to await a more favourable opportunity of cutting the pages, for the recipient knows more or less what is likely to interest him.

If any members are to have the "Abstracts", those resident abroad have the strongest claim. They are unable to attend the meetings and the library is out of reach. The cost of postage on the small publication is the same to most parts of the world and cannot be urged as a reason against general distribution. Instead of these things being recognized, and the Society doing its utmost to give its exiles a more living interest in its work, it slights them by not sending full measure of its publications.

G. W. Grabham.

Khartoum, Anglo-Egyptian Sudan.
July 29, 1914.

OBITUARY.

ALFRED JOHN JUKES-BROWNE, B.A., F.R.S., F.G.S.

Born April 16, 1851. Died August 14, 1914.

We regret to record the death of Alfred J. Jukes-Browne, which took place, after a brief illness, on Friday, August 14, 1914, at his residence, "Westleigh," Ash Hill Road, Torquay.

Alfred J. Browne was the son of Mr. A. H. Browne, formerly of St. Paul's Crescent, Camden Town. His mother was a sister of Professor J. Beete Jukes, F.R.S. He took the name of his uncle on attaining his 21st birthday and afterwards was known as Alfred Jukes-Browne.

He was educated at Cholmondeley School, Highgate, and thence entered St. John's College, Cambridge, where he passed the Natural Science Tripos in 1874, and took his B.A. degree. He was an ardent student of Natural History, and the writer recalls the pleasure with which young Browne showed him his collection of recent shells all carefully named and arranged by himself. He was always a rather delicate and ailing lad, and in later life never seemed to overcome this weakness of constitution. But his mental energy was remarkable.

On September 7, 1874, A. J. Jukes-Browne was appointed as a temporary assistant on the Geological Survey of Great Britain under Sir Andrew Ramsay and continued on the Survey for twenty-seven years, but retired on account of ill-health in 1901. In 1874 he was elected a Fellow of the Geological Society, and was a recipient of the Lyell Fund in 1885, when the President, Professor T. G. Bonney, F.R.S., spoke of the excellent work Jukes-Browne had done on the Cretaceous formation and in Glacial Geology, and of his papers on the Cambridge Greensand and his Sedgwick prize-essay on the post-Tertiary deposits of Cambridgeshire. Professor Bonney also referred to Jukes-Browne as one of his geological pupils, of whom, as his old college tutor, he was justly proud.

In 1901 the Council awarded Jukes-Browne the Murchison Medal, when the President, Professor J. J. H. Teall, F.R.S., spoke of his numerous writings on the Upper Cretaceous rocks, associating palæontology with his stratigraphical work, of his handbooks on Physical and Historical Geology for Students and his suggestive work on *The Building of the British Isles*, and other valuable services he had rendered to geological science.

He was elected a Fellow of the Royal Society in 1909.

Mr. William Whitaker, F.R.S., an old colleague on the Geological Survey, writes: "By the death of Jukes-Browne science has lost a gallant worker. The greater part of his life was a ceaseless struggle with ill-health and bodily weakness. But the alert and active mind, the resolute spirit, were victorious, and the enfeebled body was not allowed to stop the work that he loved so well, though often it must have delayed it. To those of us especially who have had the blessing of good health it has been a marvel how Jukes-Browne managed to do so much and so well. Under such adverse circumstances most men would have given way, and would have done little or nothing; but he worked until the last. Both in quality and in quantity, in the field even as well as in the study, his work might put to shame many a strong man. He was a worthy nephew of his uncle, Jukes."

His wife and son died before him, but his daughter survives her father.

Between 1871 and 1914 the GEOLOGICAL MAGAZINE credits A. J. Jukes-Browne with ninety-eight papers of his own, and nine joint papers—with C. V. Bellamy on Cyprus; with Wm. Hill on the Gault and Chalk Marl; with Professor J. B. Harrison (2) on the Geology of Barbados; with C. J. A. Meÿer on the Greensand and Chloritic Marl; with J. Milne on the Cretaceous of Aberdeenshire; with J. Scanes on the Upper Greensand of Mere and Maiden Bradley; with W. Whitaker on the Geology of the Wash; and with R. Bullen Newton, F.G.S., on the Devonian of Torquay.

His separate publications include—

Student's Handbook of Physical Geology. Two editions.

Handbook of Historical Geology. 1886.

Handbook of Stratigraphical Geology. 2nd edition, published in 1912.

Handbook, *The Building of the British Isles*. 3rd edition, 1911.

The Cretaceous Rocks of Britain, in 2 vols. Mem. Geol. Survey.

And many other small memoirs for the Geological Survey, and contributions to the Geological Society, Geologists' Association, and the Malacological Society. There is an unpublished MS. of Jukes-Browne's in the Editor's hands dated July 12, 1914, on a Boring at Marston, near Devizes.